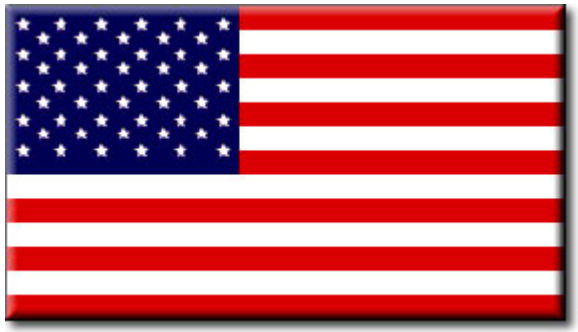


Prospect of Indo-US Collaboration

Developments in India

Indo-US Collaboration on Accelerator and HEP

Shekhar Mishra

Fermilab

Fermilab and India Collaboration

History Of Indo-US S&T Cooperation

- 1950's Era of Green revolution facilitated with the PL 480 Funds
- 1960's Establishment of IIT, Kanpur; NCERT, N. Delhi
- 1970's NASA-ISRO – SITE (Satellite Instructional Television Expt) Indo-US S&T Sub-Commission
- 1980's Gandhi Reagan Science & Technology Initiative (STI) US-India Fund (USIF)
- 1990's Indo-US Fellowships Program DST-NSF S&T Collaboration Program (Ongoing) NASA-NOAA / ISRO-DST MoU (Ongoing) DBT-NIH Health Programs (Ongoing)
- 2000 Indo-US Science & Technology Forum (Ongoing) Indo-US Biotechnology Alliance (Ongoing)
- New Agreements are being discussed in space, high technology etc.

Indo-US Science and Technology

- Sharing a Common Vision for the New Millennium

- Indo-US Science and Technology Forum is established on March 21, 2000 to facilitate and promote the interaction, in India and the United States, of government, academia, and industry in science and technology.

- There are several other agreements in place for S&T collaboration and new agreements are being discussed.

http://www.indousstf.org/

India HEP Collaboration in world

- Indian scientists have been collaborating at CERN for decades.
- Its participation and contribution to LHC has given India an Associate Member State status with CERN.
- India has build accelerator and detector components for LHC/CMS.
- India also participates in experiments at KEK and DESY.

20 Years of Indo-US HEP Collaboration

- Indian Scientists have collaborated in a High Energy Physics Experiments from early 80's at Fermilab and other US laboratories.
- At Fermilab the collaboration started with Fixed Target Experiment and has now extended to D0 and Accelerator.
- Argonne National Laboratory has collaborated with India on Superconducting cavity development.
- Six Institutes from India collaborates on the STAR experiment at BNL.
- Many US laboratories have worked with Indian laboratories
- Indians are on staff of every US laboratories, universities and major US industries.

Proposal to DST/DAE to support Indo-US Collaboration on Accelerator and Detector R&D

International Linear Collider: Accelerator

International Linear Collider: Detector R&D

High Intensity Proton Linac for Neutrino Physics

4th Generation Light Sources

Shekhar Mishra for
Indo-US Collaboration

Indo-US Collaboration History

- Since the start of the discussion in Dec. 02 with Prof. Ramamurthy we have been making progress.

- Interaction Meeting on Linear Collider and Neutrino Physics was held in New Delhi, Nov. 03. (Attended by 19 US and 70 Indian scientists) Followed by visits to CAT & TIFR.

- Indo-US working group was established by Prof. Ramamurthy and Prof. Witherell, Director of Fermilab.

- Working group met at Fermilab in Aug. 04 and a program of collaboration was discussed. All US and 2 Indian members participated.

Indo-US Collaboration History (cont)

The following model was considered optimal to initiate such exchanges:

- US laboratories initially would accept say up to two Indian scientists at each of the collaborating US laboratories.
  - The project and details of each visiting persons would be decided by mutual interest. It is hoped that this will be an avenue to involve working level persons and hence most of these visitors are expected to be junior scientists and engineers.
  - The exchange visit period would be of say for minimum of 6 months each (although shorter length visit could still consider if need be) and there should be some overlap between the incoming and outgoing scientists at the various labs.
- US scientists will visit Indian laboratories for specific topics of interest to develop collaboration and building contacts, for example
  - Commissioning of Indus-II
  - Review of Indian accelerator projects
  - Holding Indo-US Accelerator Schools
  - Participation of US scientists in Indian conferences

Indo-US Collaboration History cont.

- Funding for the travel and stay of these scientists in the two countries was discussed.
  - At present the US and Indian laboratories do not have funds earmarked to support scientific exchange between the two countries.
  - Host laboratories can provide office space, administrative and computing support.
  - Sources for living and travel expenses have to be found. It was decided that the Indo-US Accelerator R&D Working Group look into several sources of funding to support these visits.
- There are two existing Indo-US agreements for scientific exchanges that can be used to fund this collaborative research. It is also possible that India may have other funding mechanism to support these activities.
  - The Indo-US Science Forum: for short visits, attending workshops etc
  - India DAE and India DST funds long visits by Indian scientists
  - US DOE funds long term visits by US scientists

Action Item: Four proposals will be submitted to funding agencies (Oct. 04)

- International Linear Collider (ILC): The ILC is the primary goal of the accelerator R&D collaboration. It is realized that to achieving this goal we must collaborate on other accelerator projects. We will submit a proposal to Indo-US Science Forum to support travel related to the Accelerator R&D. PI: Shekhar Mishra, USA and Vinod Sahni, India

- High Enery Physics Detector R&D: India has already made significant contributions to High Energy Physics Detector R&D and construction as well as their installations in some labs in USA. India could therefore naturally participate in a International Linear Collider Detector collaboration and related R&D. We will submit a proposal to DST-NSF to support this activity. PI: Harry Weerts, USA and, (nominee to be decided by) India.

- Neutrino Physics: Fermilab, BNL and many institutions India have considerable interest in Neutrino physics. We will submit a proposal to DST-NSF to support this activity. PI: Doug Michael, USA and (nominee to be decided by) India.

- Fermilab and BARC/TIFR teams in India have considerable interest in astroparticle physics of which gamma ray astronomy is an important part. There is an opportunity to forge new partnership especially in the context of planned Indian Gamma Ray Telescope at Hanle, Ladhakh. PI: and (nominee to be decided by) USA and R Koul, India.

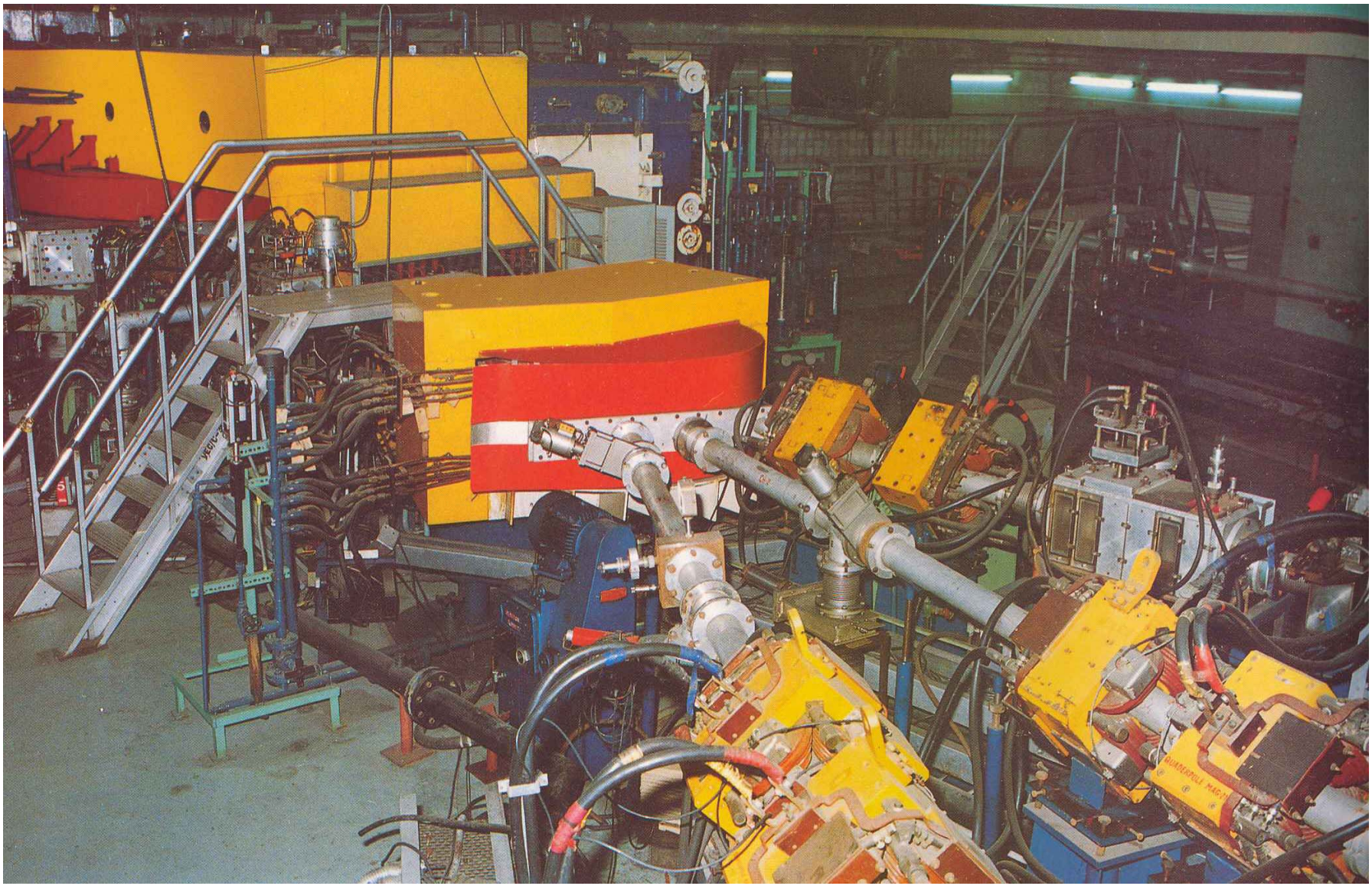
Progress Since Nov. 03

- Administrative:
  - Dr. Vinod Sahni has been appointed to be the new member of ICFA. After 15 years of no representation and reorganization India is a member of ICFA.
  - Dr. Sahni has also become a member of ILCSC.
  - India has been invited to participate in the Finance/Funding Agencies discussion for the Linear Collider Funding held at London.
  - Dr. Atul Gurtu from TIFR represented India at a meeting end of last year.
  - Indian scientists have been named to International Committee for ILC.
- Scientific:
  - Indian scientists have received invitation to give invited accelerator talks at International conference in consultancy with the Indo-US working group. (Germany, PAC05, LCWS05, Snowmass…)
  - US Scientists have received invitations to participate in Indian conferences
  - Importance of Indian collaboration is being discussed at every meeting of ILC
  - Indian scientists have started participating in ILC work at Fermilab.
  - ILC technology selection was made on Aug. 20th 2004. This made the Indo-US common interests closer.

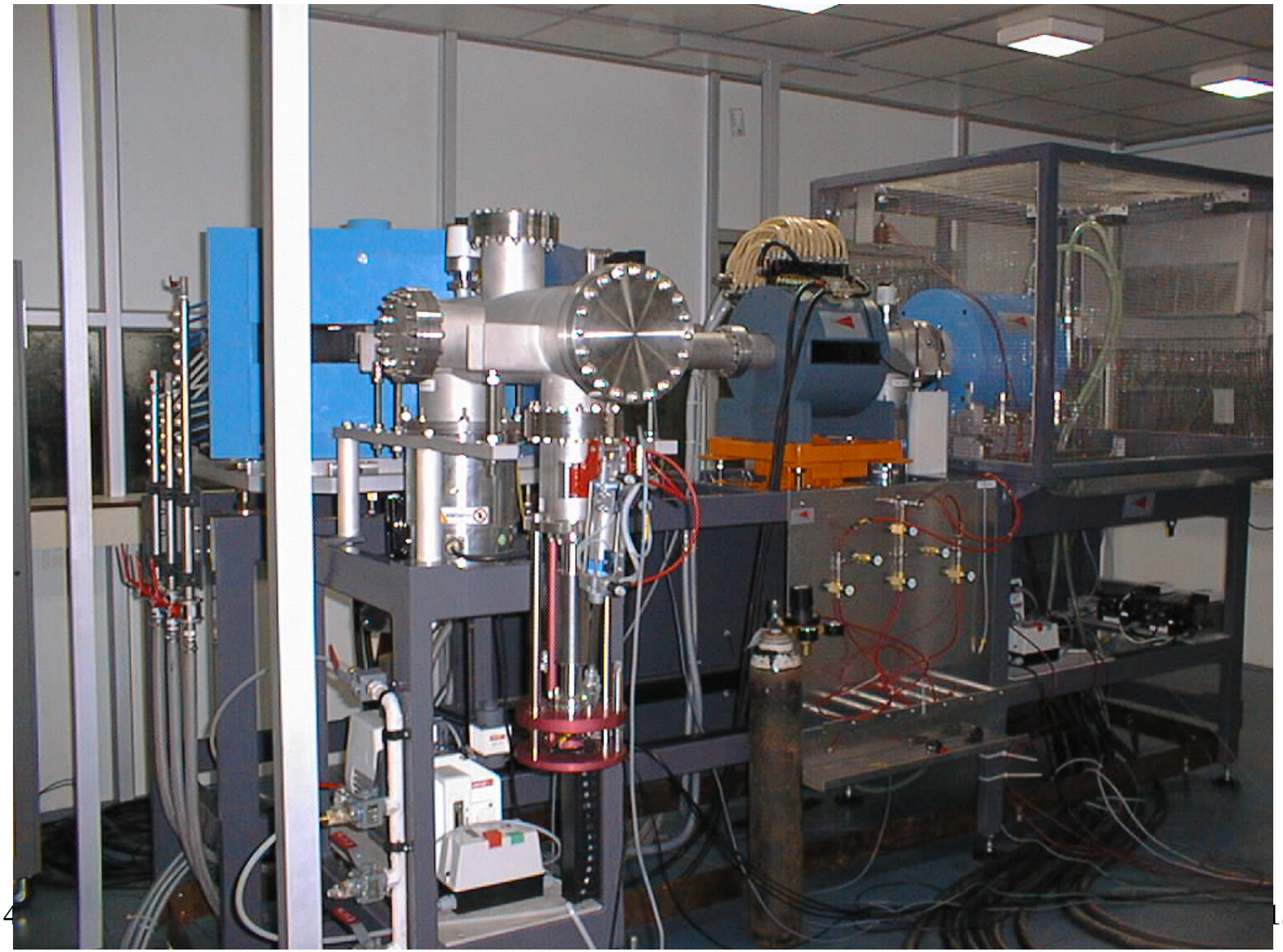
Indian Laboratories

- During the last 3 years US scientists have visited all the major Indian Laboratories.
- We also attended Indian Conferences and our impression is very positive regarding the progress in India.
- VECC
- CAT
- TIFR
- NSC
- We heard presentations from several other labs and universities.

224 CM VARIABLE ENERGY CYCLOTRON AT VECC

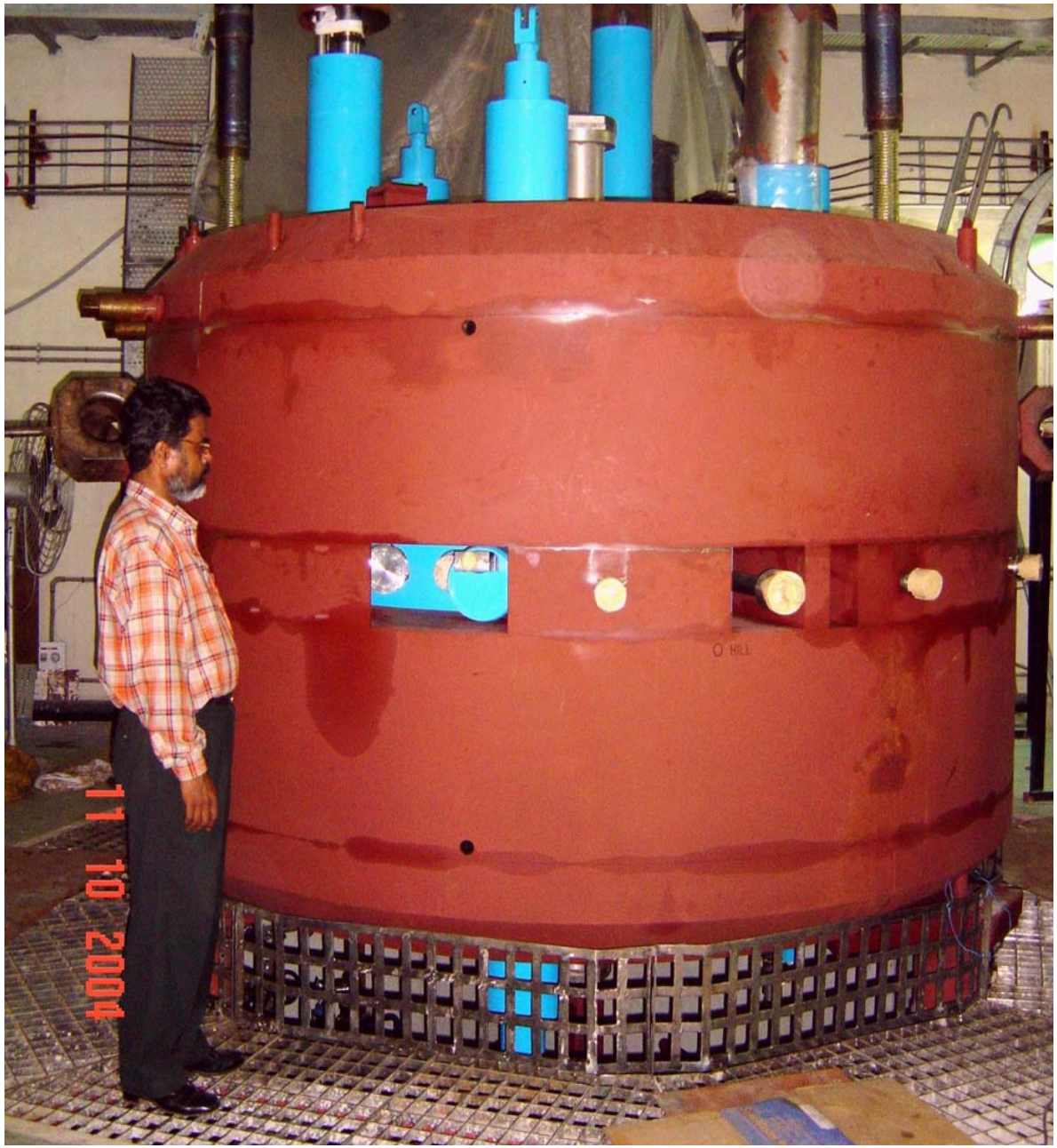


ECR-2 ION SOURCE AND ANLYZING MAGNET



UPPER POLE CAP WITH POLE TIP ASSEMBLY IS BEING PLACED ON TO LOWER ASSEMBLY

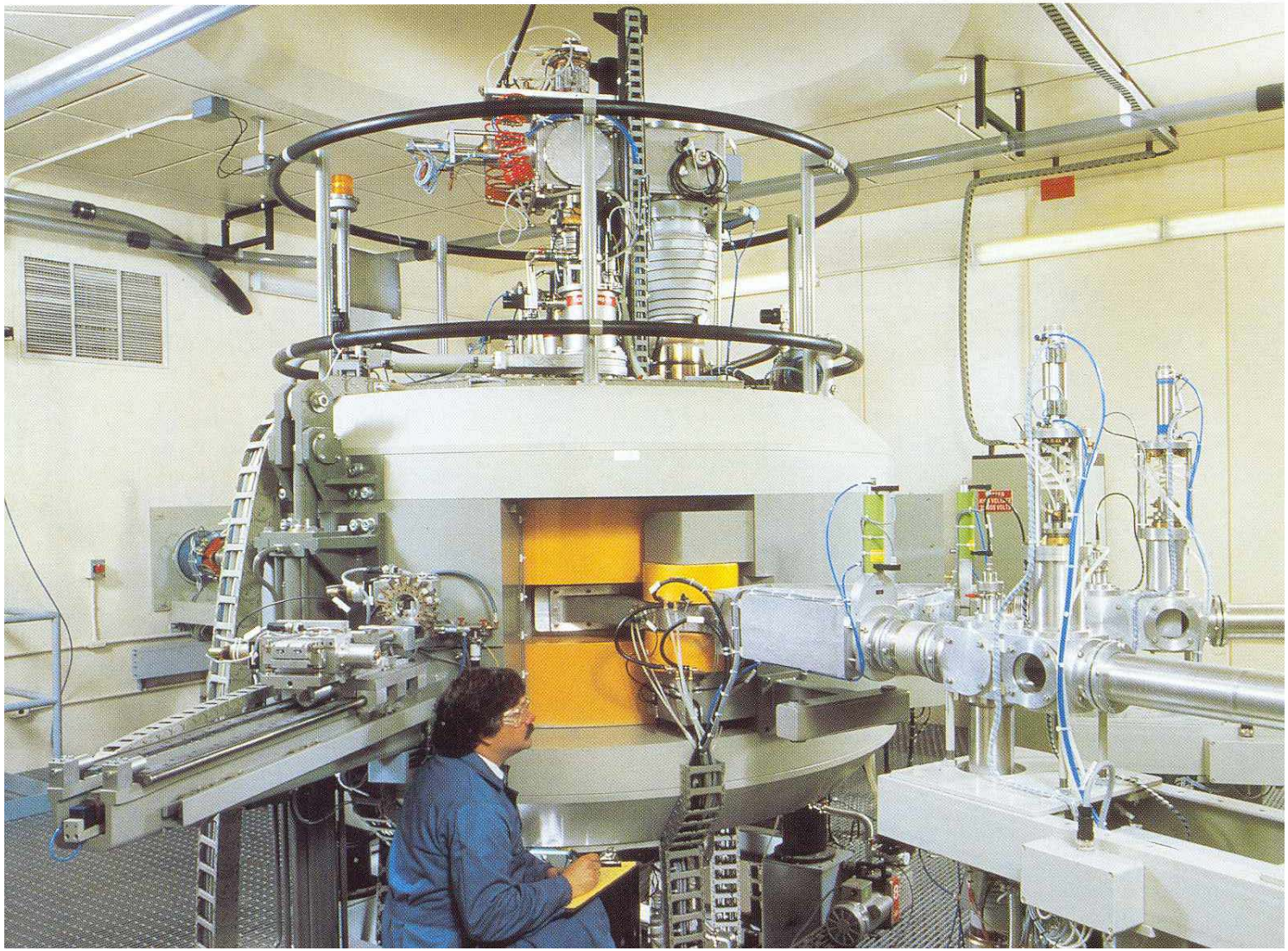
CYCLOTRON MAGNET WITH CRYOSTAT INSTALLED IN IT



PART OF THE CRYOGENIC DELIVERY SYSTEM AT SITE

JANUARY 11, 2005 : COIL AT 4.2 K

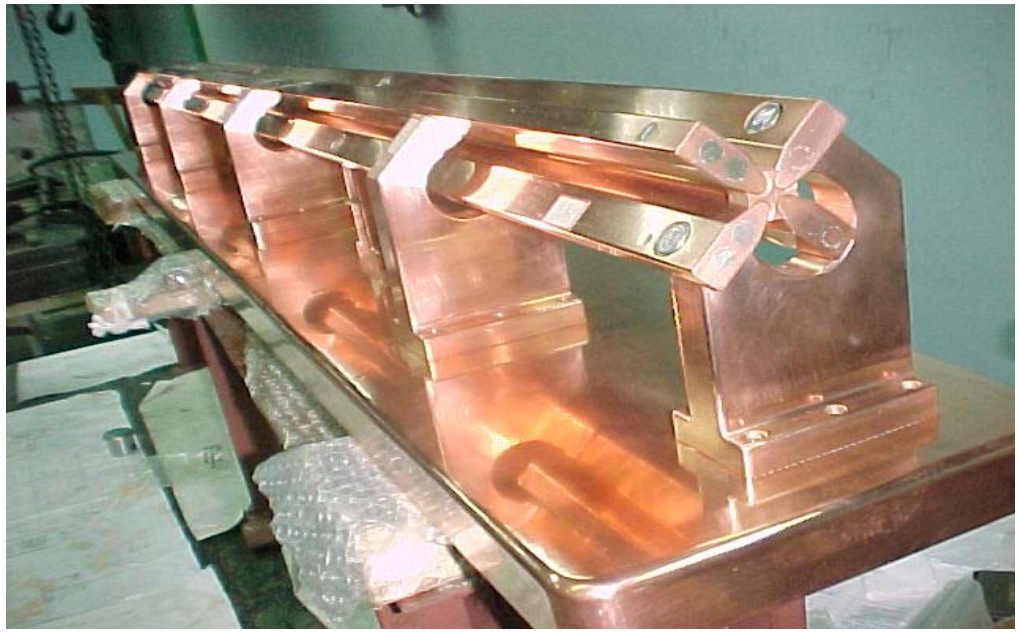
Medical Cyclotron



4 MV MEDICAL LINAC JEEVAN JYOTI - 2

GAMMA CAMERA

RFQ cold model

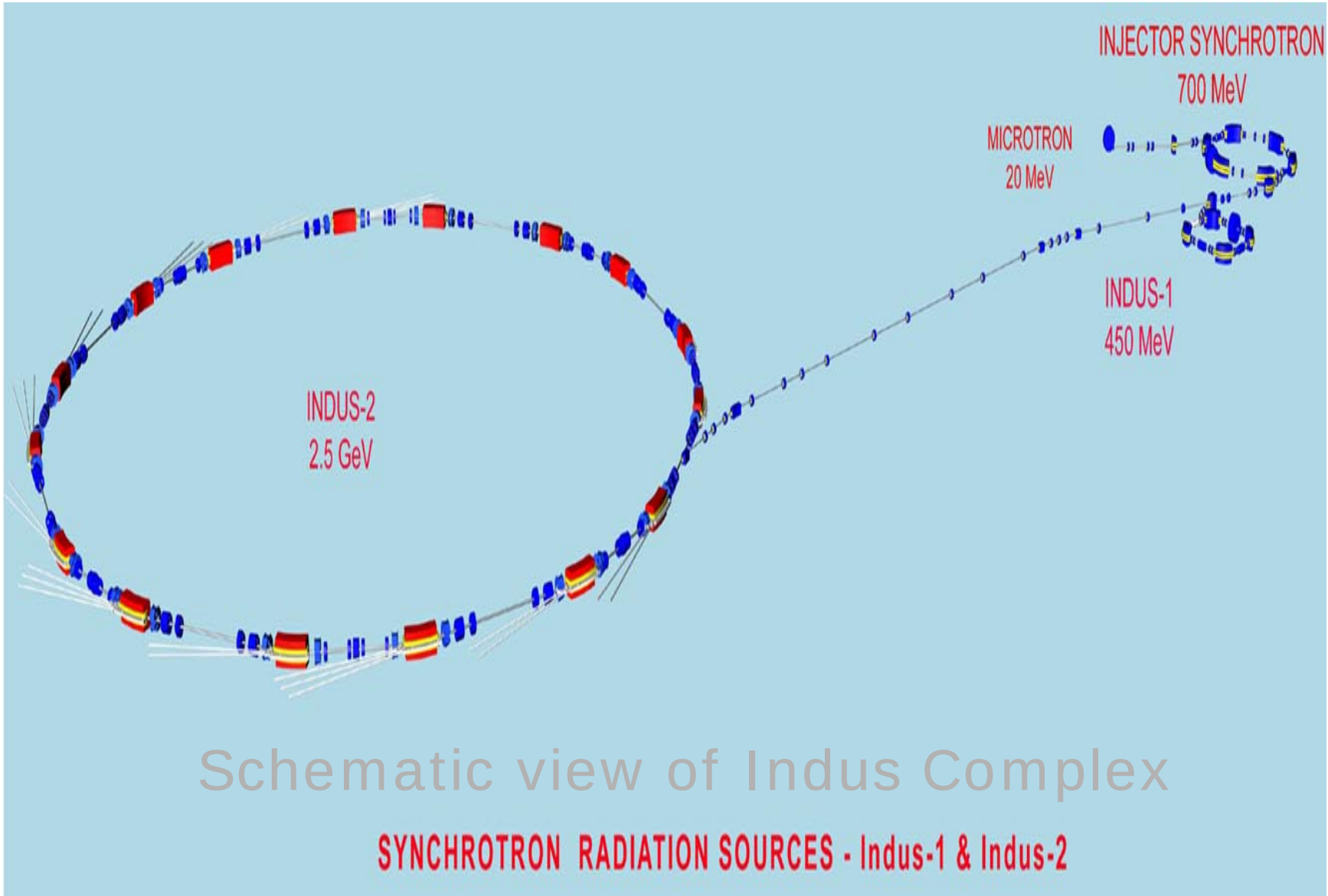


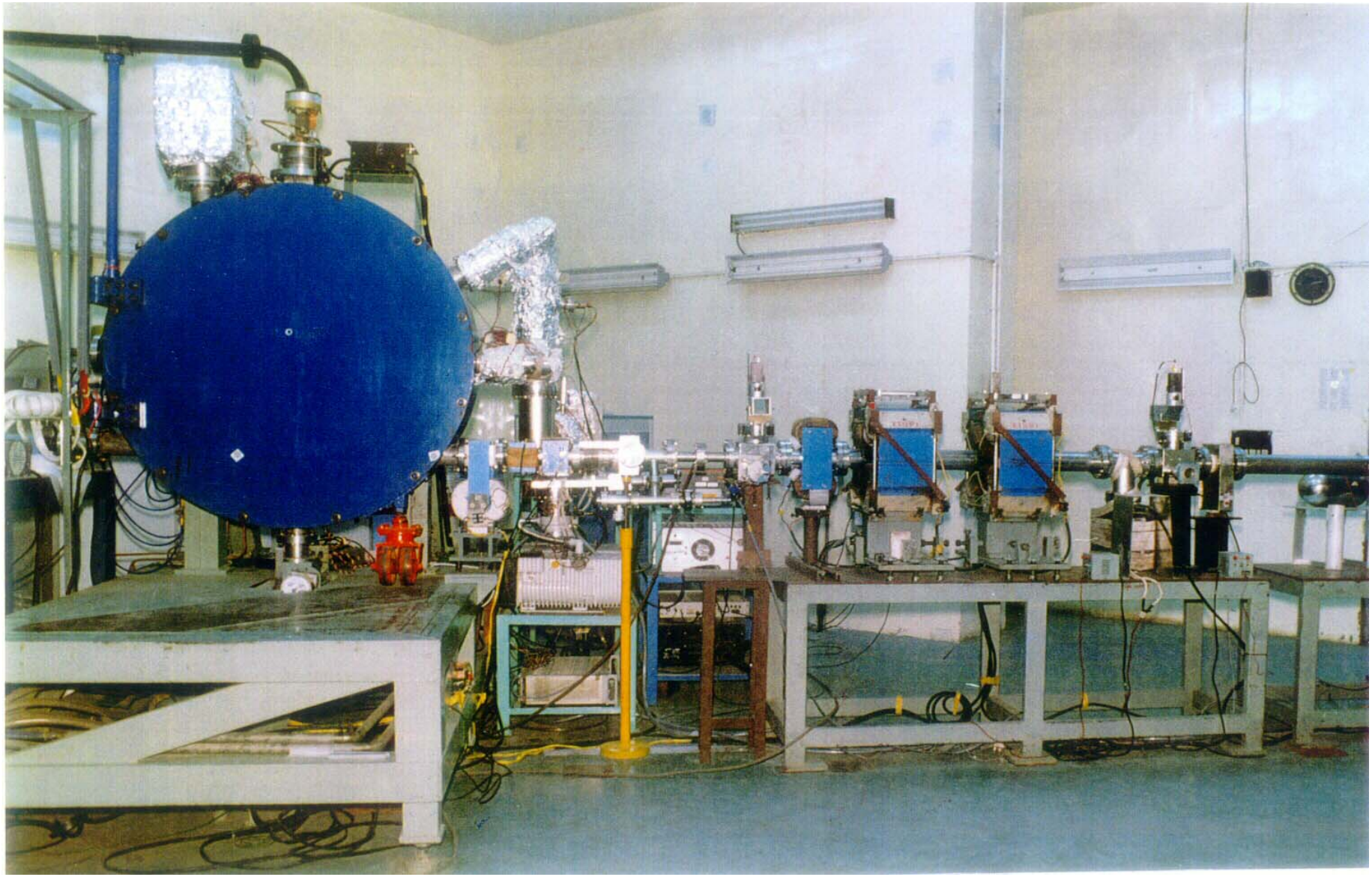
Results of RFQ Cold model tests

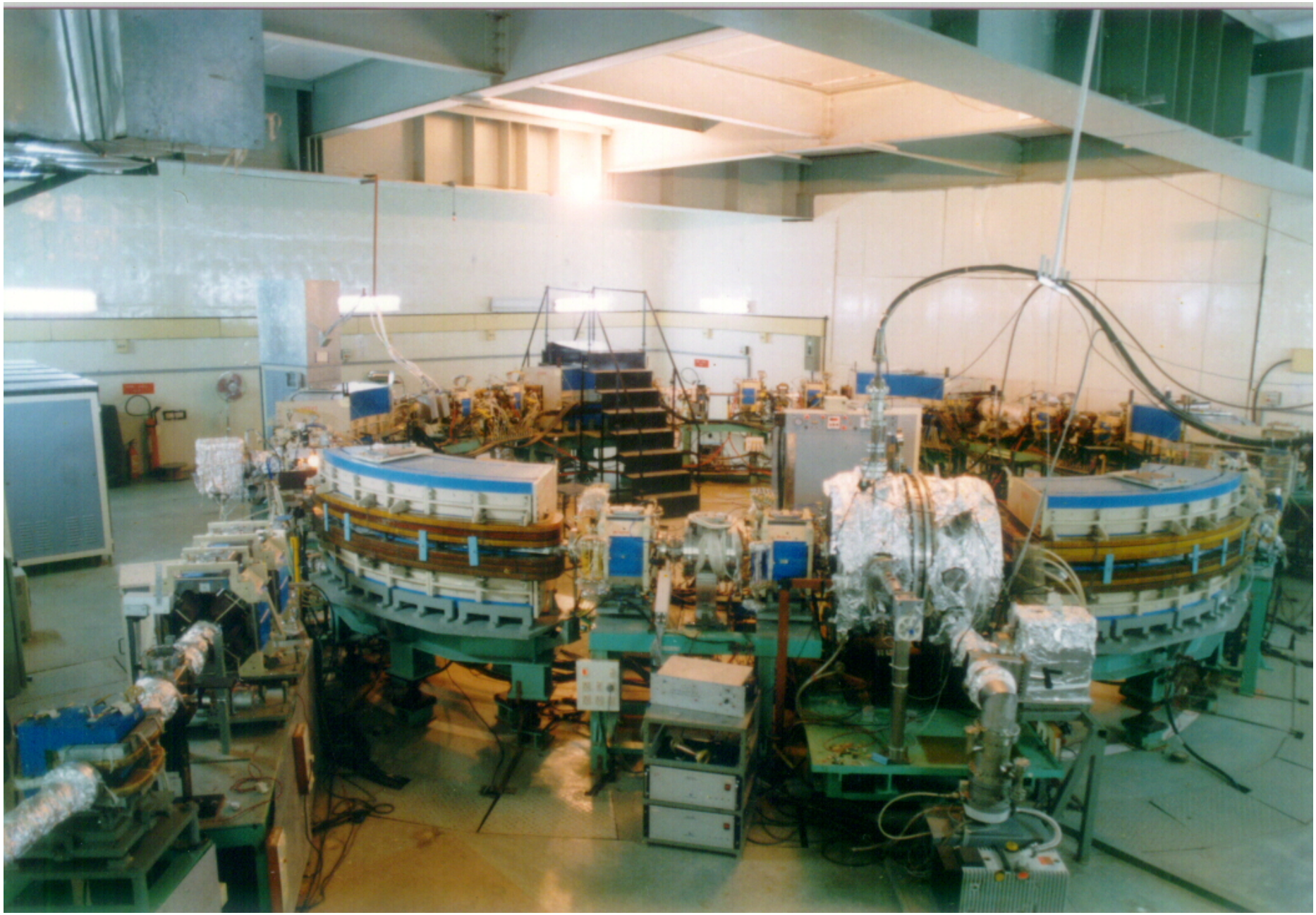
Quantity	Measured	Expected (theoretically)	MAFIA (full scale)
f (MHz)	73.00	70.00	35
Q	3500	6951	9830
R_p (kΩ)	35	61.52	87

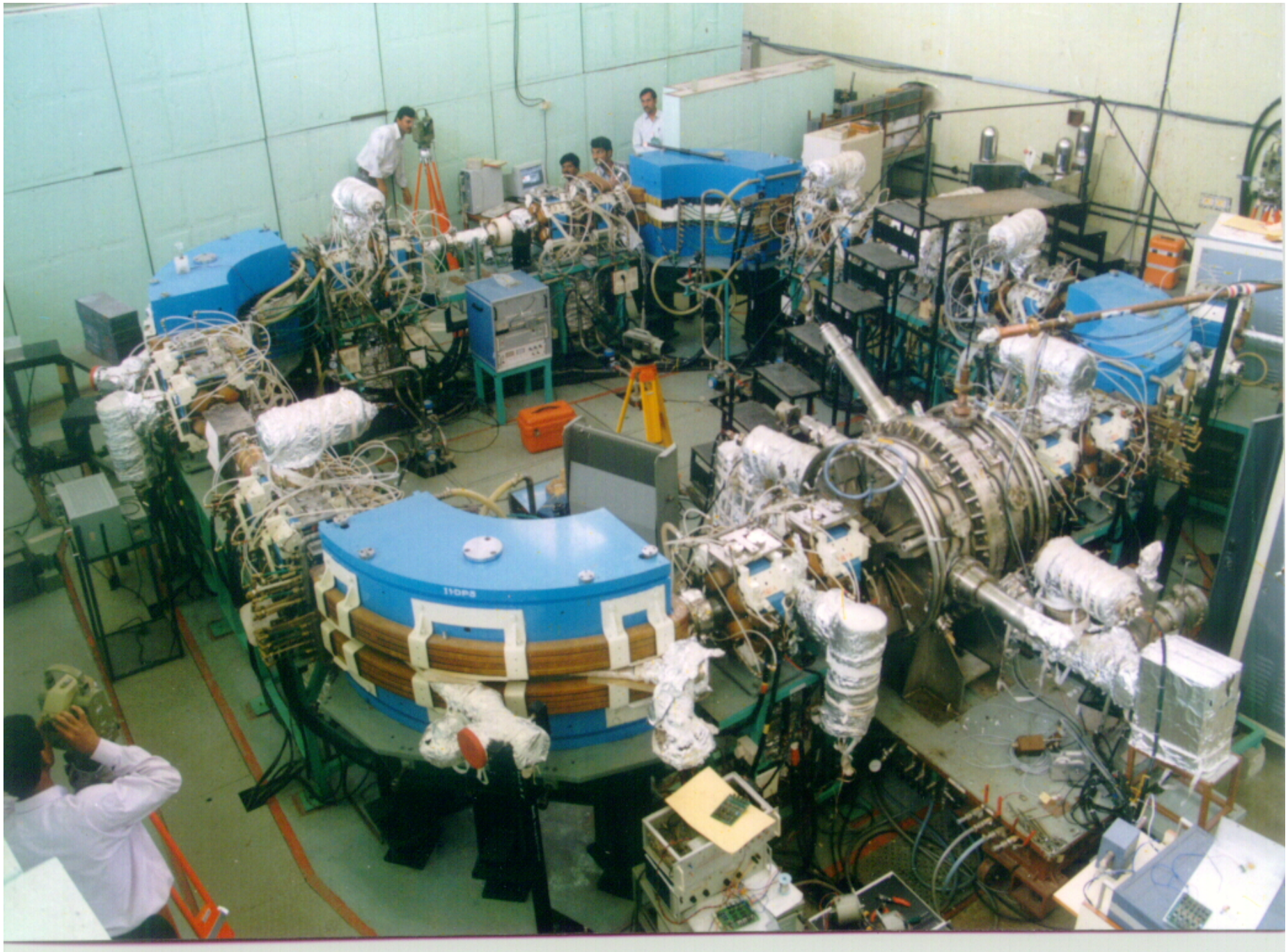
Center of Advanced Technology

- ***<u>Main ongoing accelerator related activities at CAT</u>***
  - **1. Synchrotron Sources Indus-1 & Indus-2**
  - **2. DC/RF Electron accelerators (0.5 – 10 MeV) energy for radiation processing applications**
  - **3. Development of photo-cathode gun for high quality electron accelerator; PWT based electron accelerator + undulator for THz radiation**
  - **4. International collaboration eg DAE-CERN for Large Hadron Collider**
  - **5. Design studies on proton accelerator for SNS source meant for CMP & MS studies**

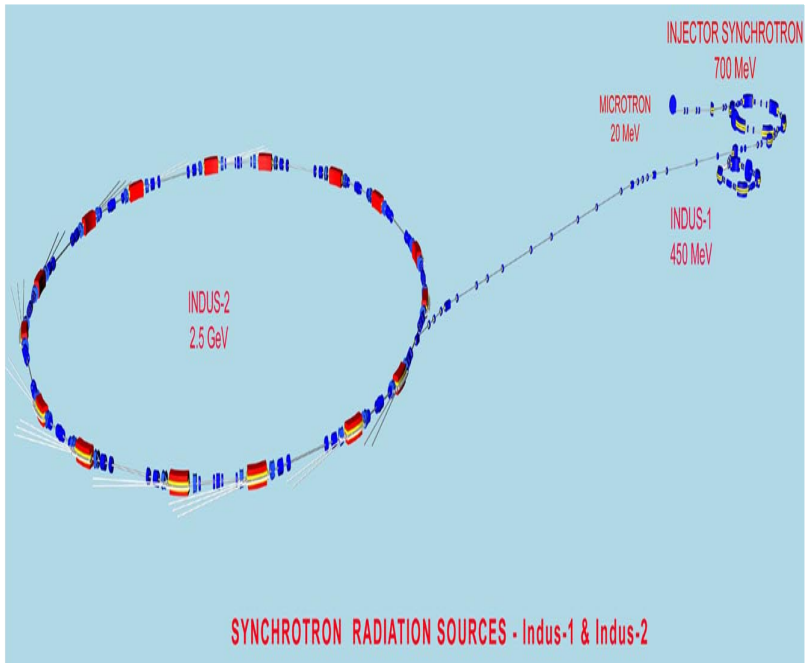

INJECTOR SYNCHROTRON
700 MeV
MICROTRON
20 MeV
INDUS-1
450 MeV
INDUS-2
2.5 GeV
Schematic view of Indus Complex
SYNCHROTRON RADIATION SOURCES - Indus-1 & Indus-2

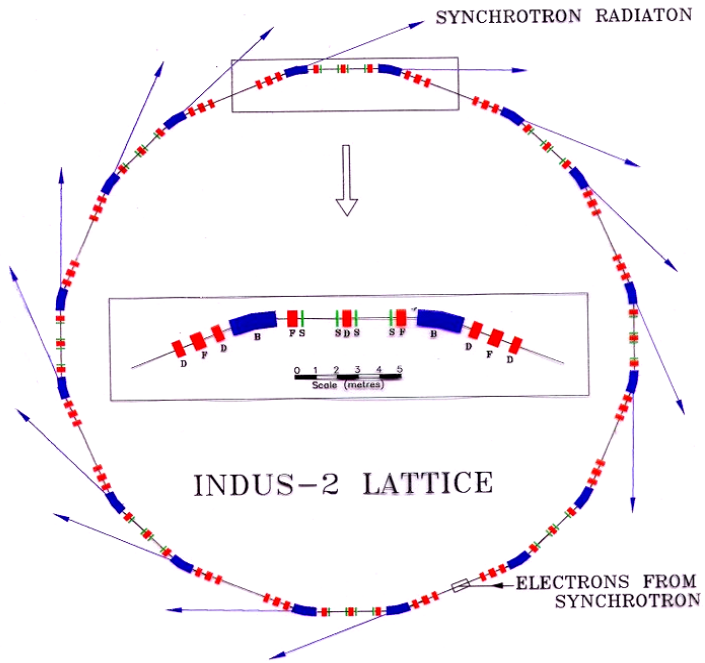





110P3

Indus-2 and its layout





INDUS-2 OVERVIEW

Important Dates and Features:

1992: Conceived

1996: Work commenced for 2 GeV energy

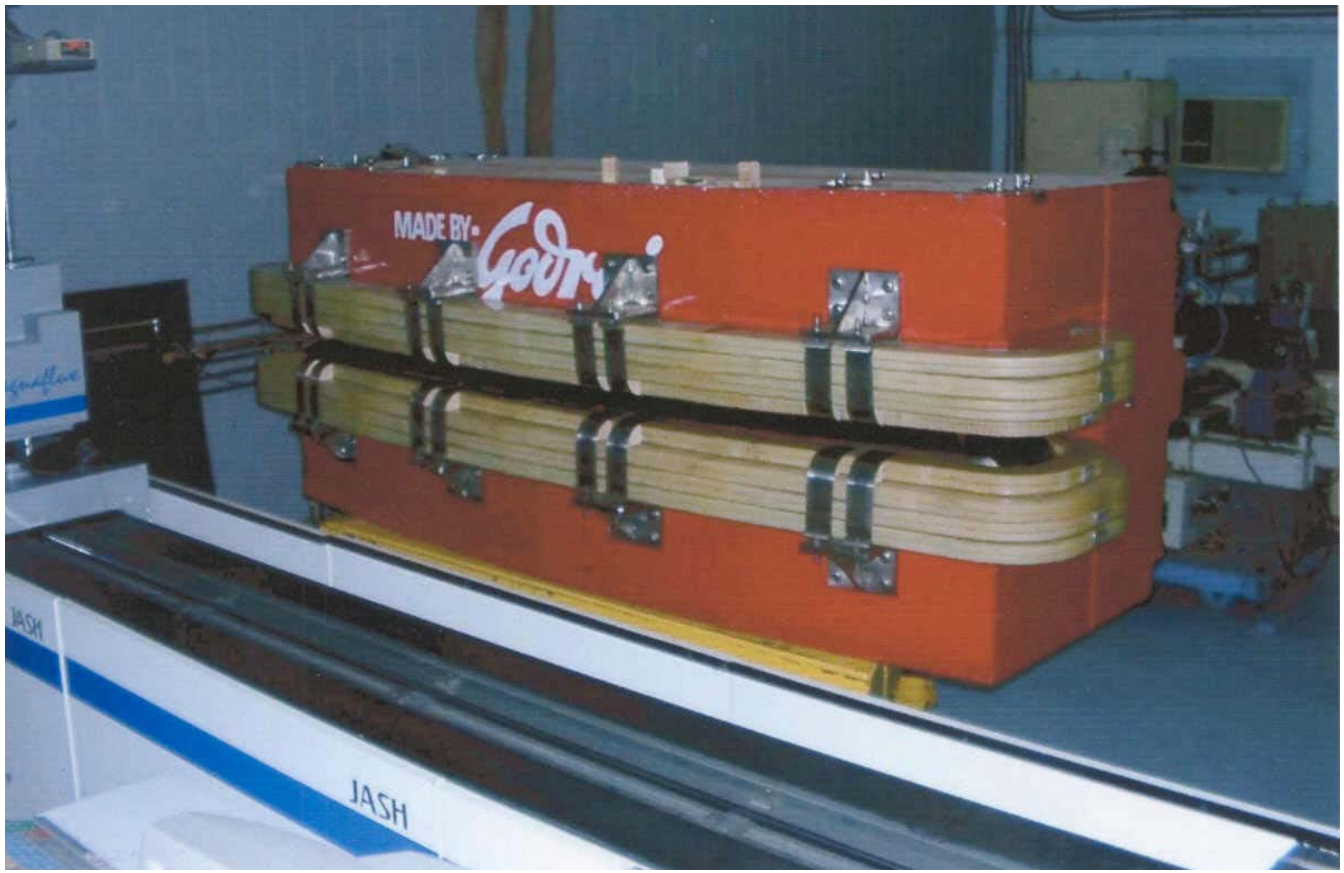
Nov. 1997: International Advisory Committee – Energy enhanced to 2.5 GeV and RF frequency raised from 189 MHz to 505 MHz

Present Cost: 95 Crores (20 Million USD)

Indigenous Systems Developed and Built: Vacuum chambers, magnets, power supplies, beam diagnostics, RF power system

Imported Items: RF cavities, Klystrons, UHV valves

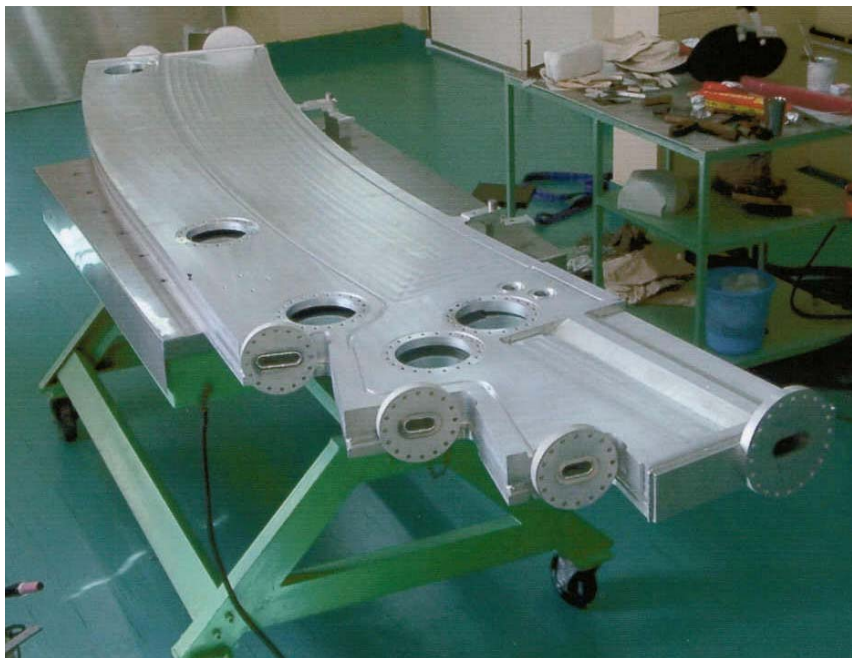
Main Dipole Magnet for Indus-2 made by Godrej, Mumbai



Quadrupoles & Sextupoles made at CMTI & CAT

Dipole Chambers

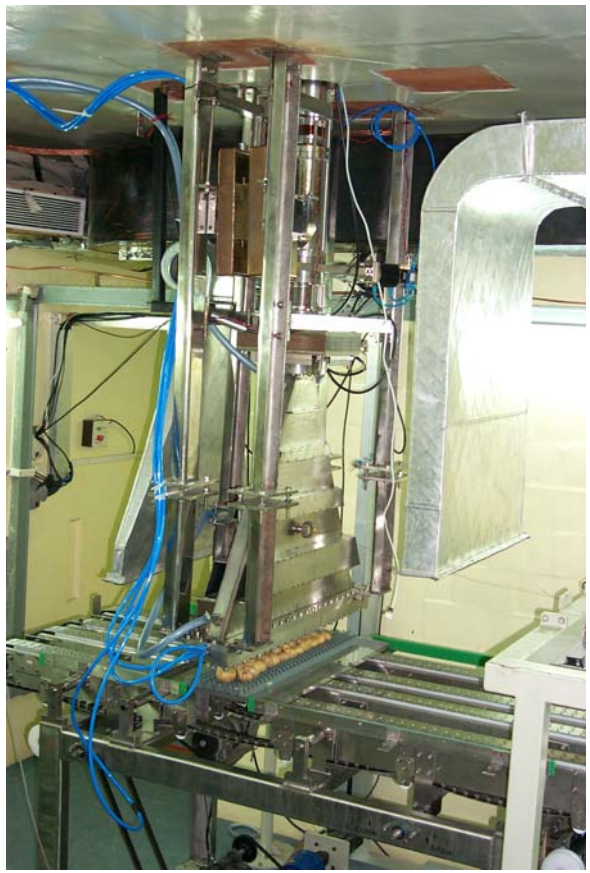
- Material: Aluminium alloy A5083-H321
- Two beam ports at 5^0 and 10^0 in each dipole chamber
- Additionally, port at 0^0 is also provided in five dipole chambers for insertion devices



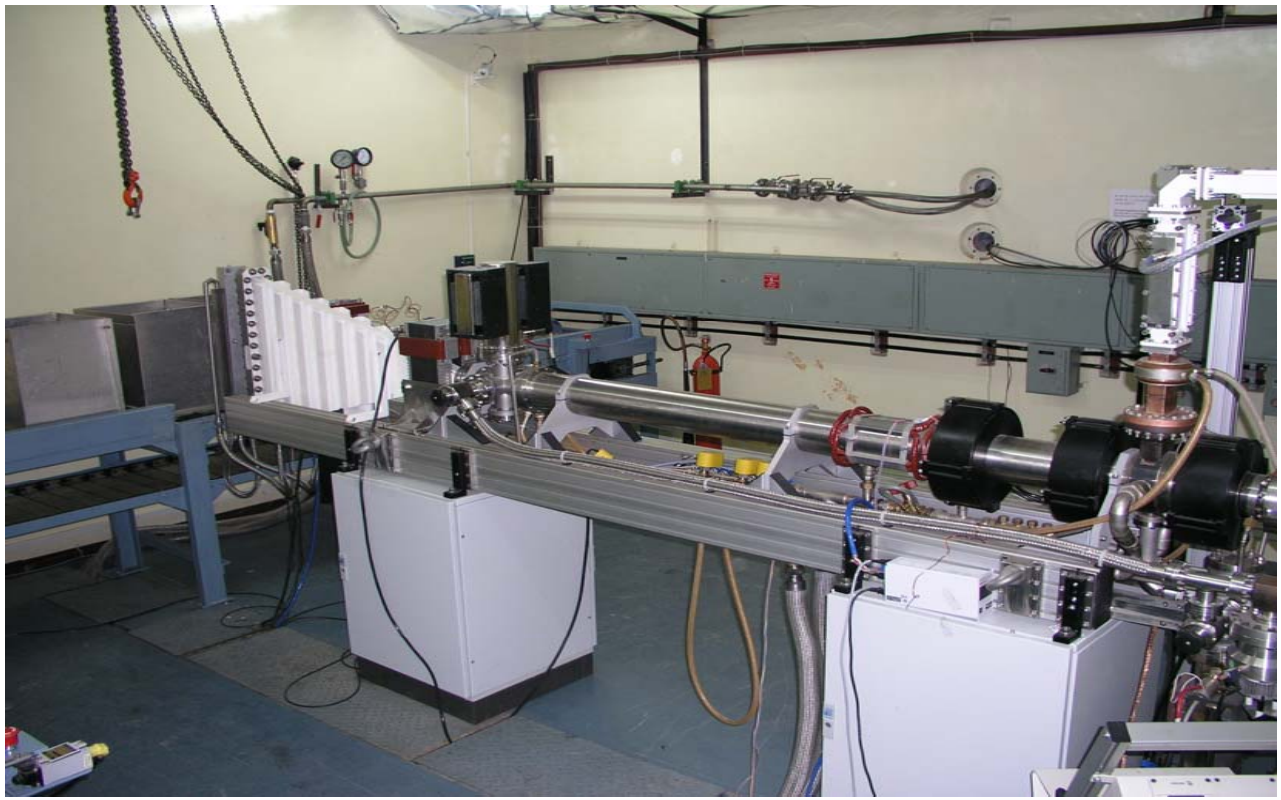
RF Cavities in a Straight Section of Indus-2 Ring

View of various magnets in Indus-2

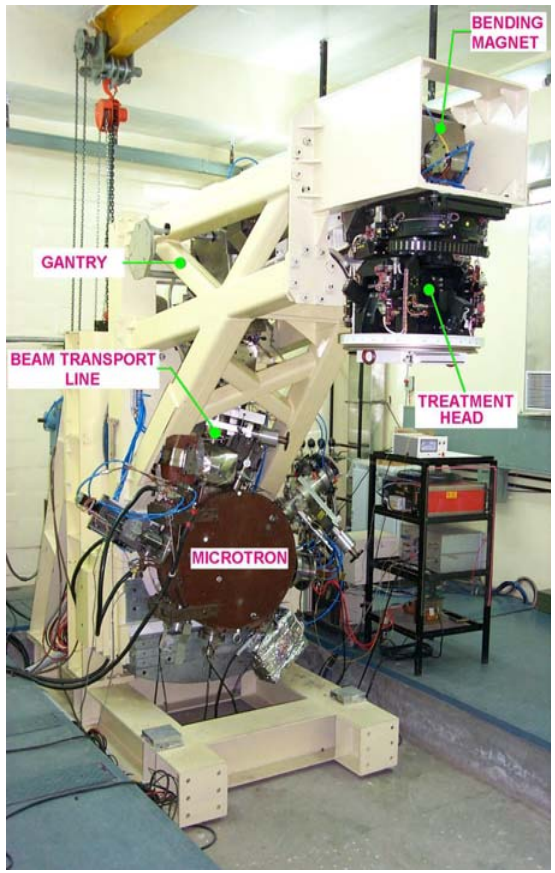
0.3 - .75 MeV Industrial DC Accelerator



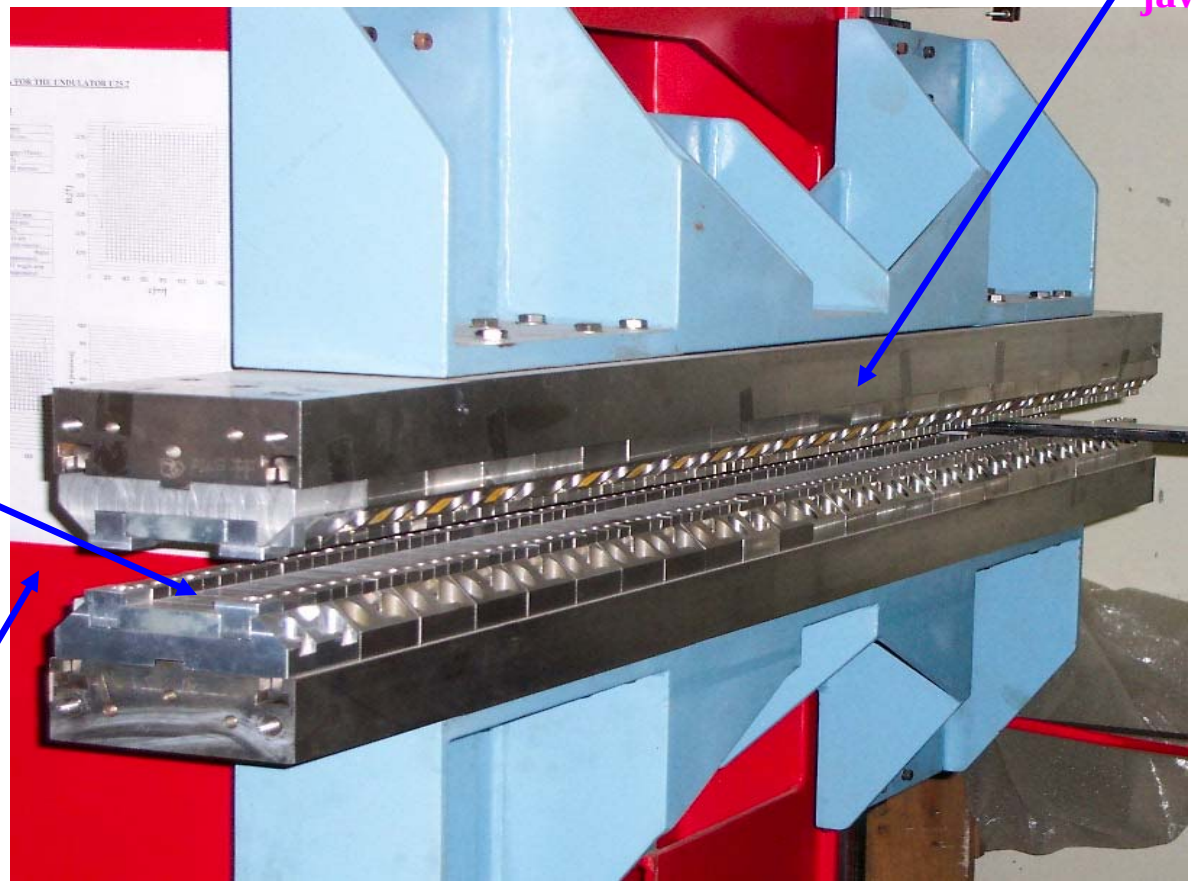
10 MeV Electron Accelerator for Radiation Processing Applications



Microtron based prototype irradiator for life science related work

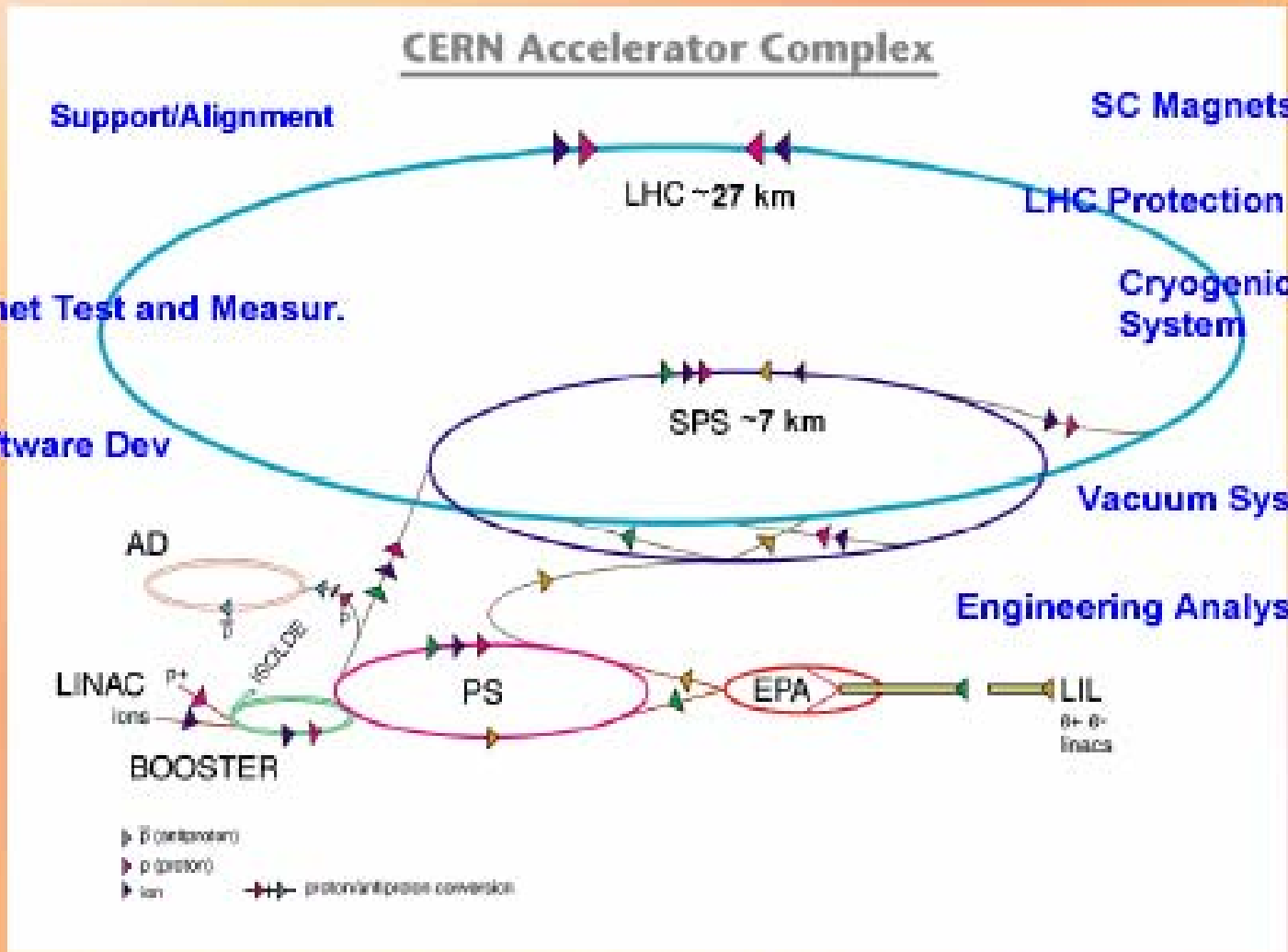


Undulator



One of two sections of the CUTE-FEL undulator: planar, PPM, 5 cm period, 25 periods. Gap variable from 33-100 mm. Maximum undulator parameter = 0.8.

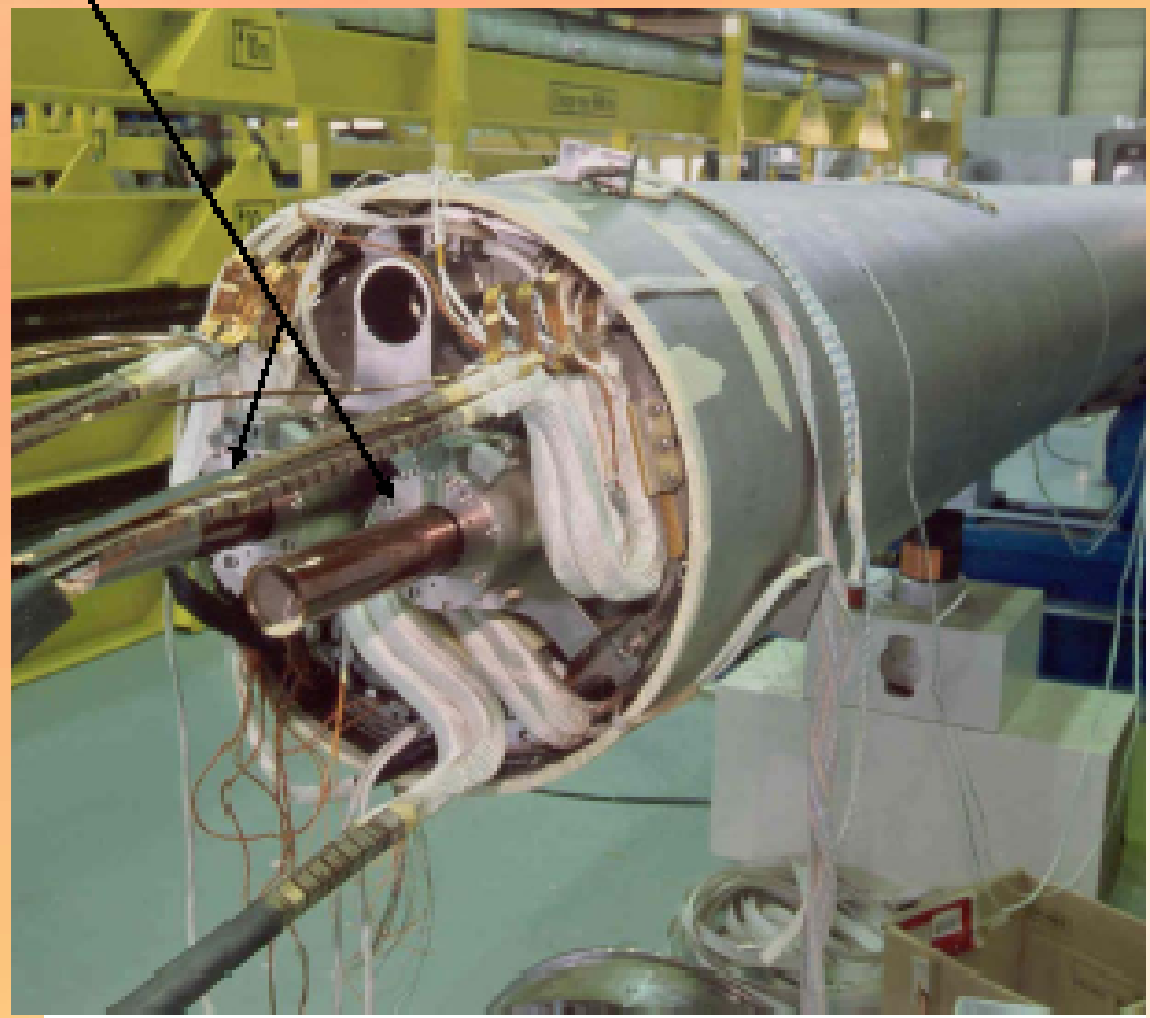
LHC String-2 Assembly with some components supplied by India



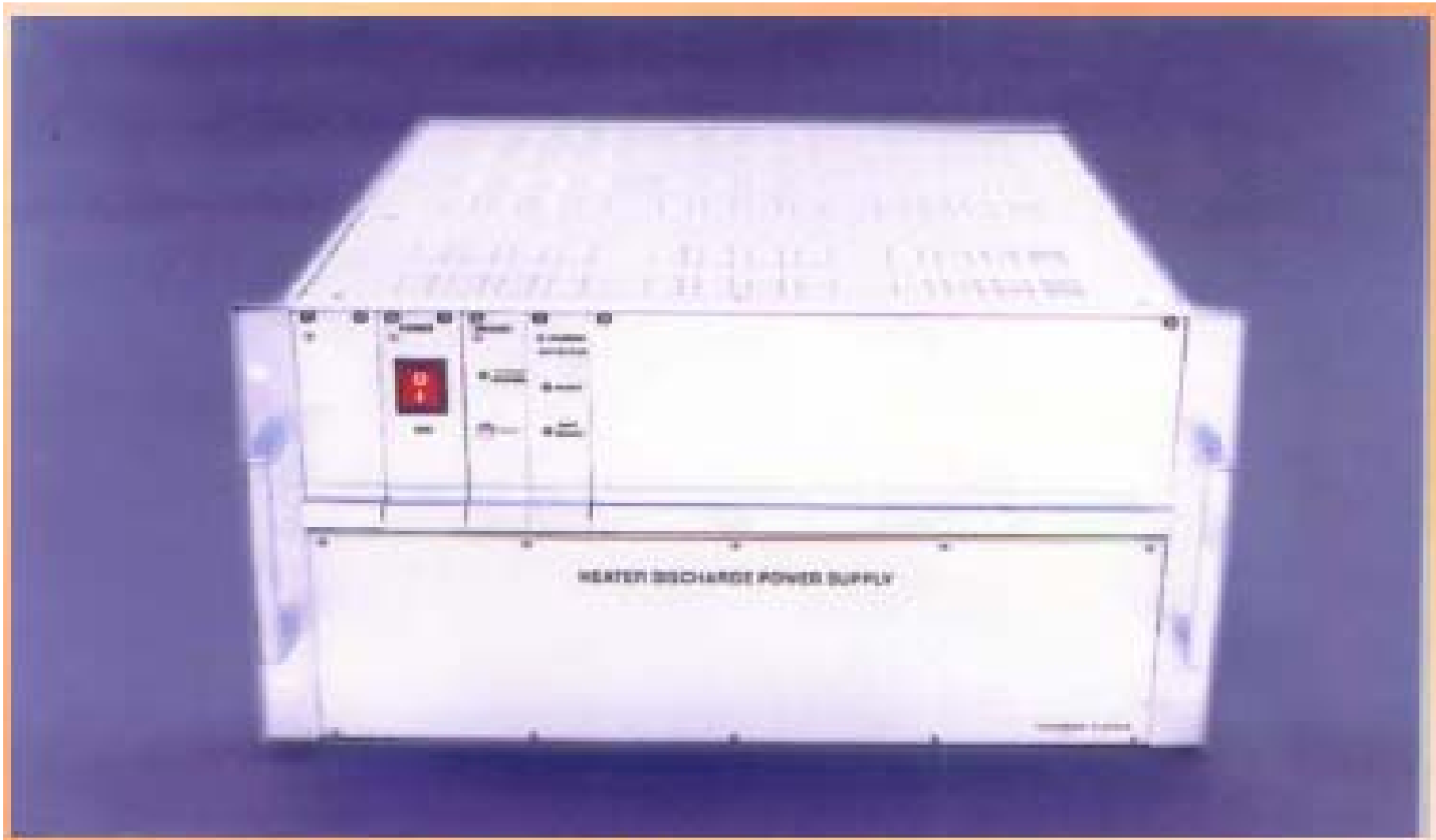
Indian Contributions – LHC domains

MCS & MCDO Corrector Magnet on main dipole magnet

- To correct the systematic field errors of the LHC Main Dipole
- They Share the same cryostat as that of Main Dipole
- Their proper functioning is as important as Main Dipole



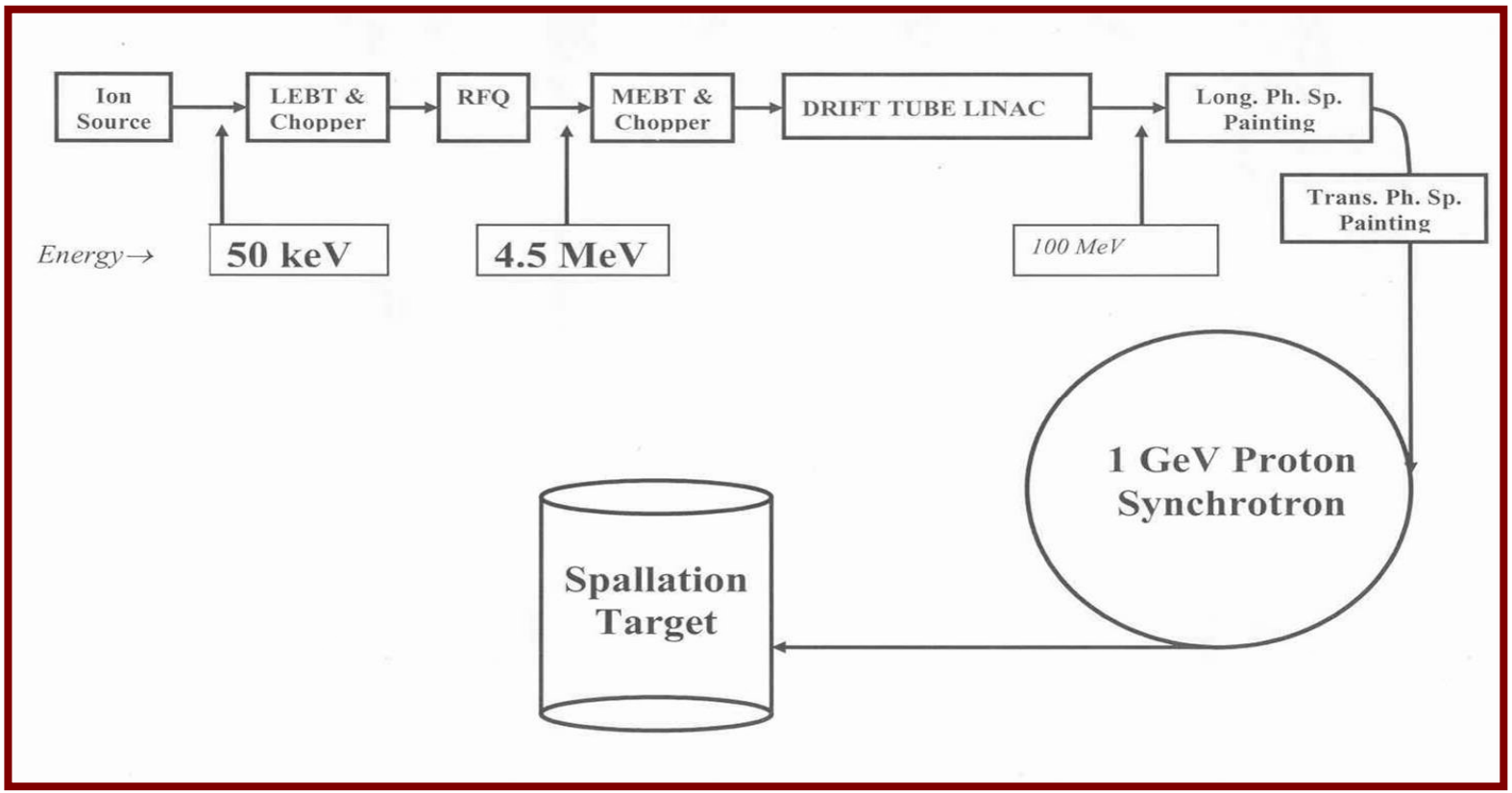
End view of the LHC main Dipole

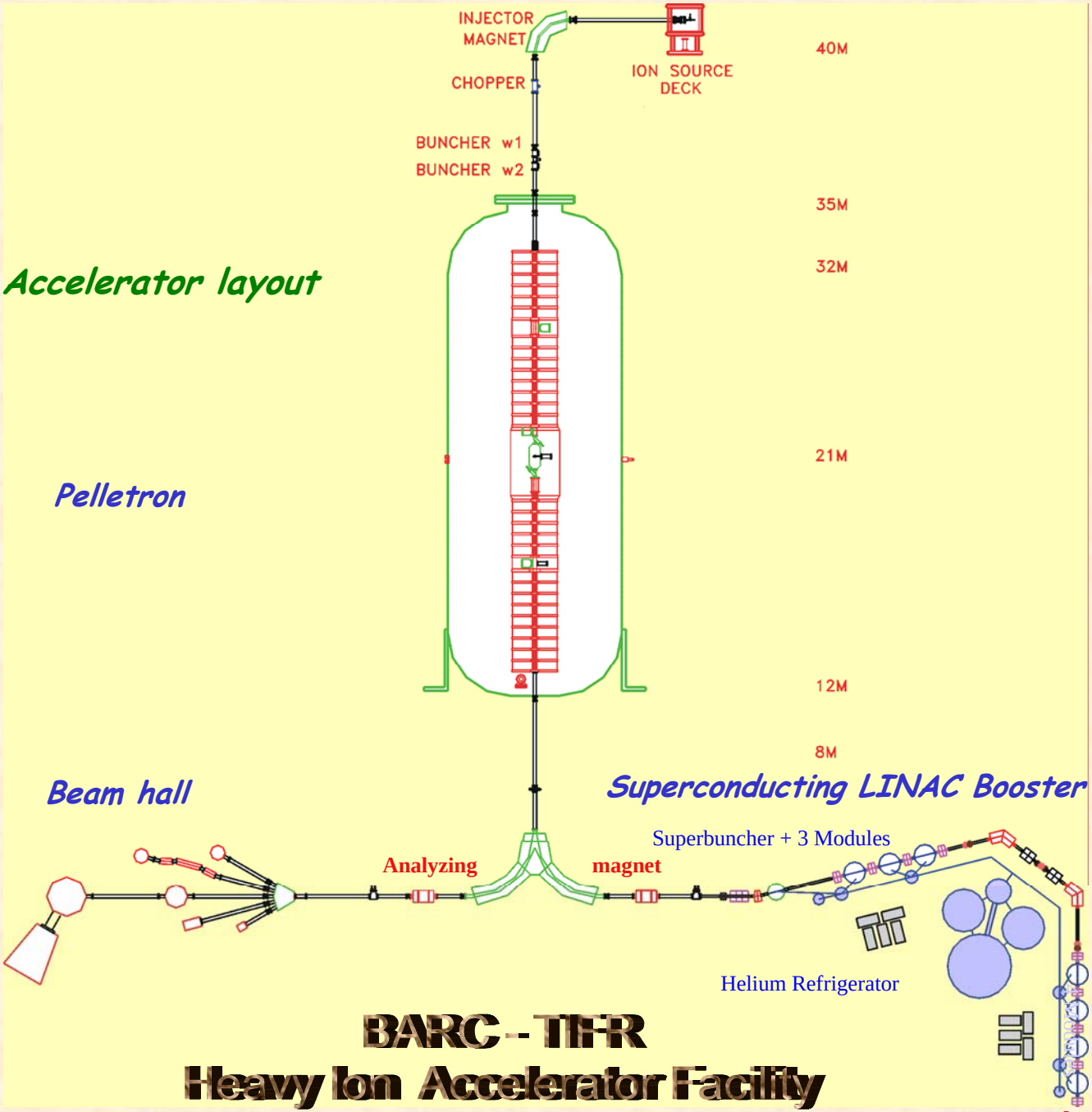


Prototype Quench Protection System Power Supply unit (QPS P/S)

Pre-Series of control electronics for circuit breaker
(energy extraction system)

Schematic Layout of SNS

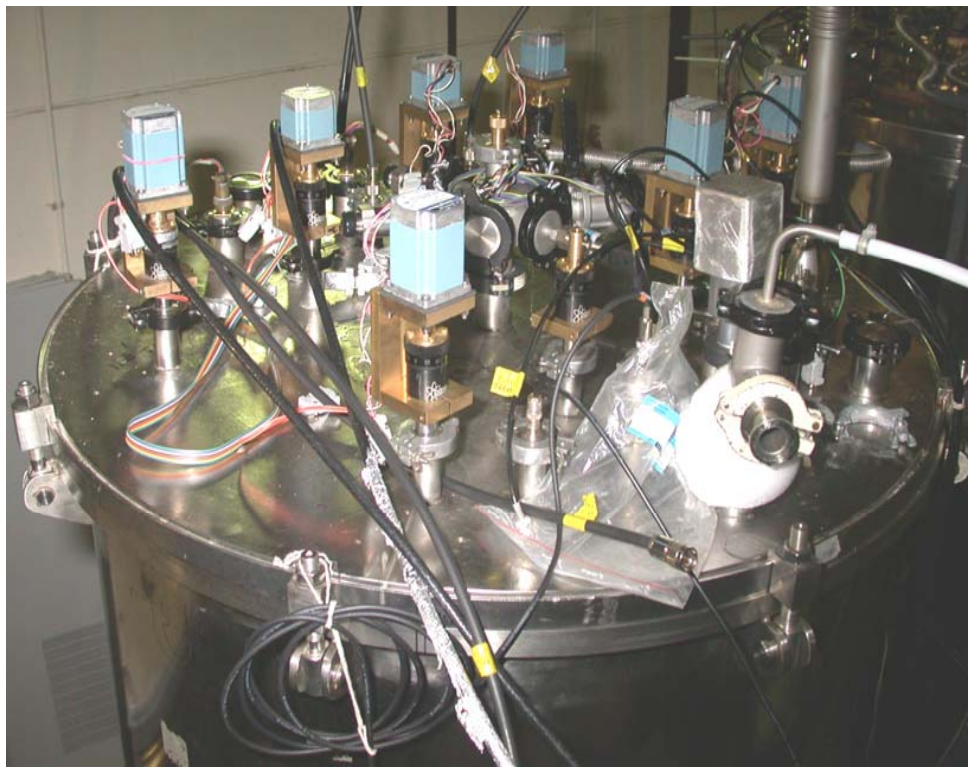




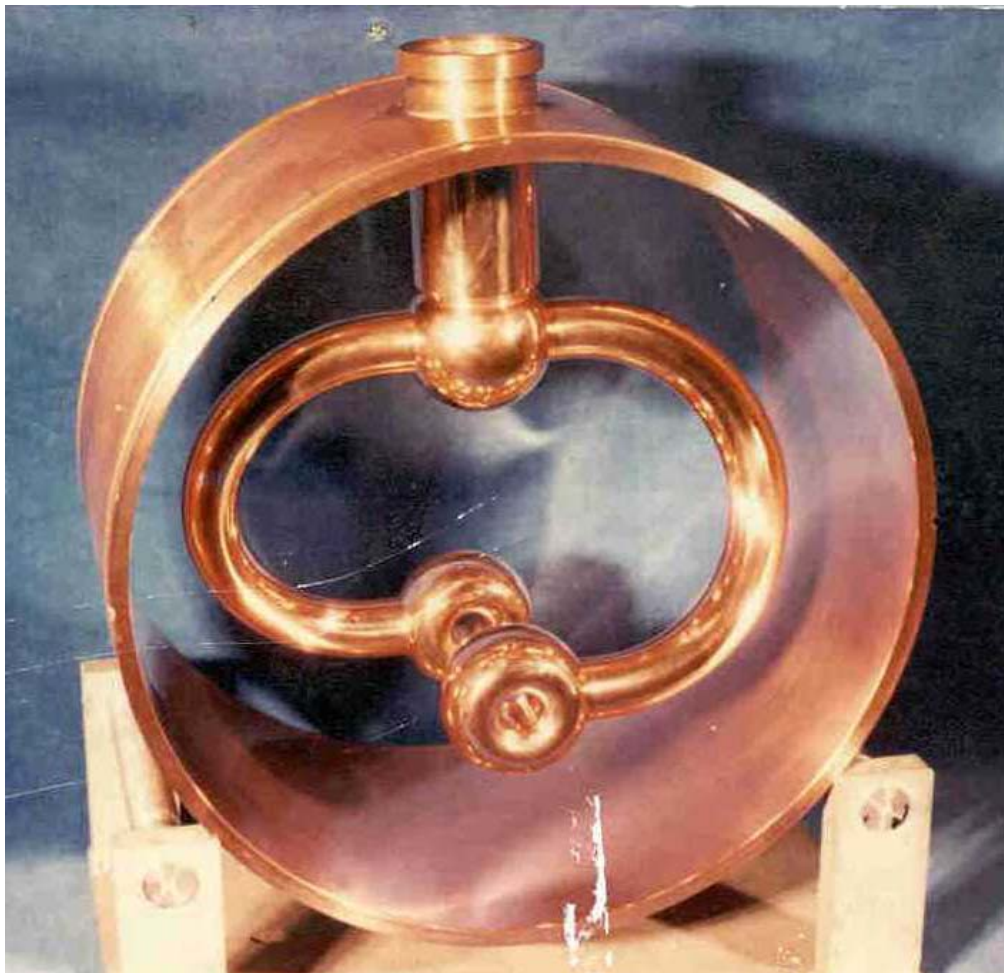
BARC – TIFR
Heavy Ion Accelerator Facility

Module Cryostat

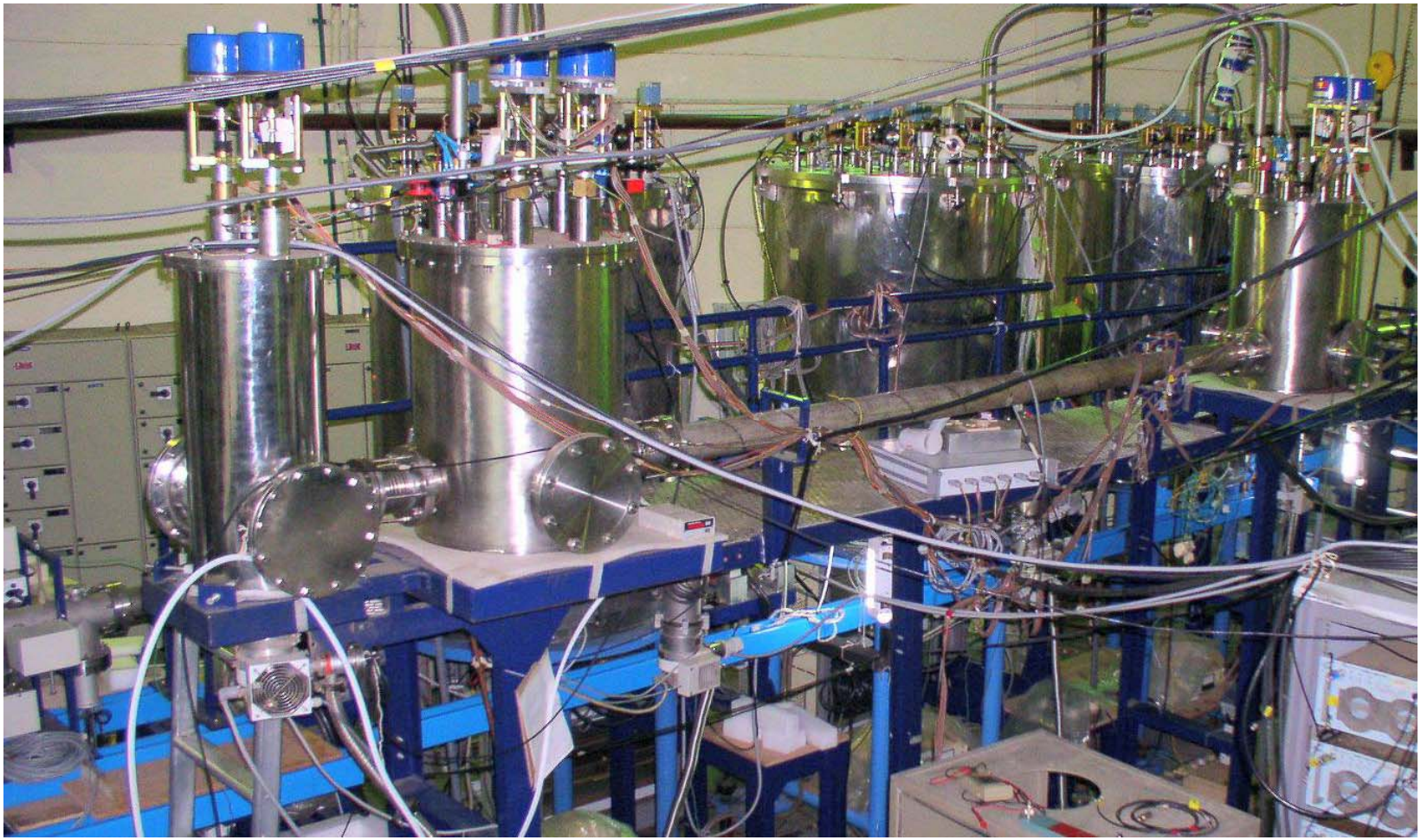
Top view of the module



Super-buncher

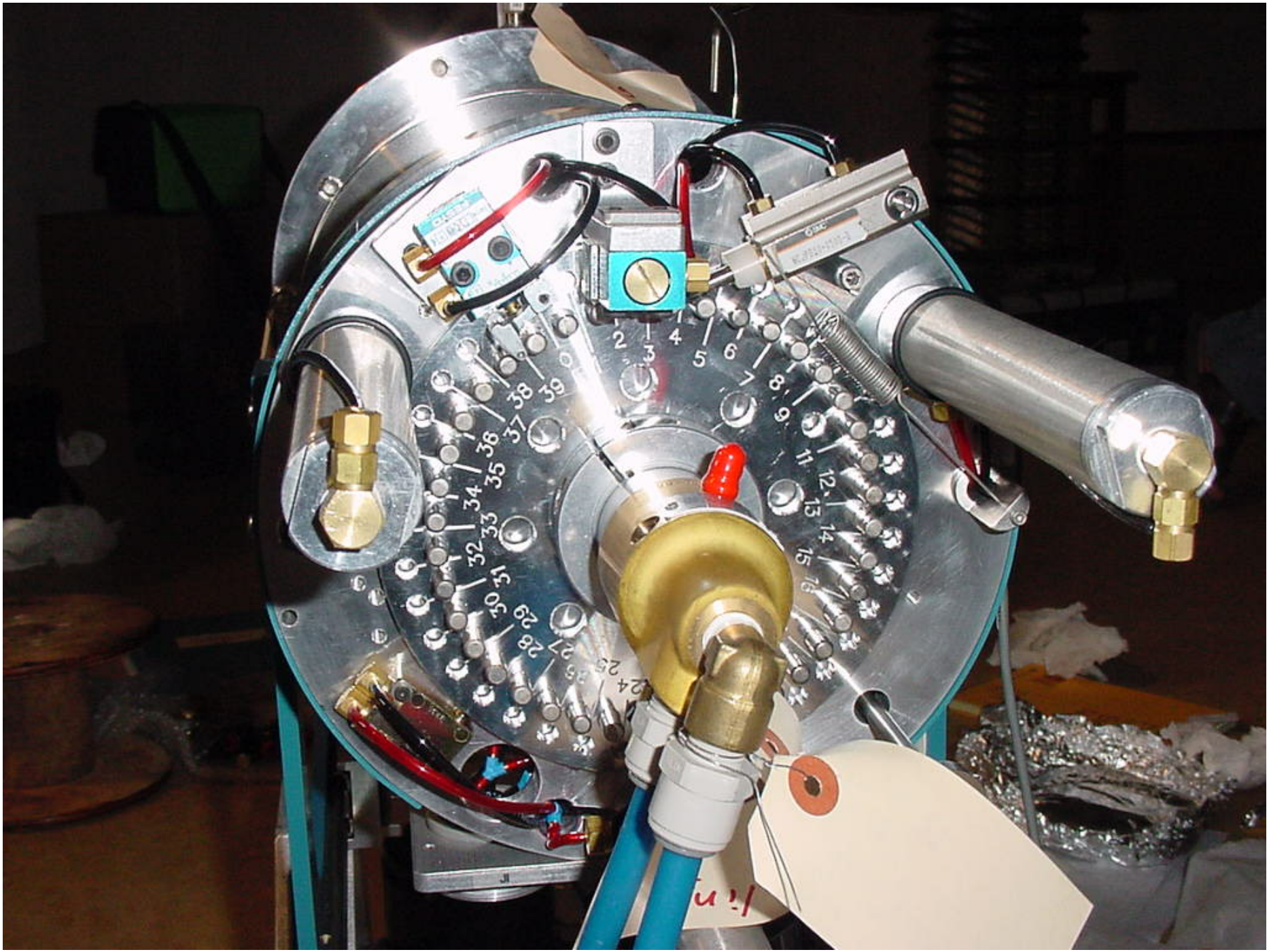


Split-loop Resonator



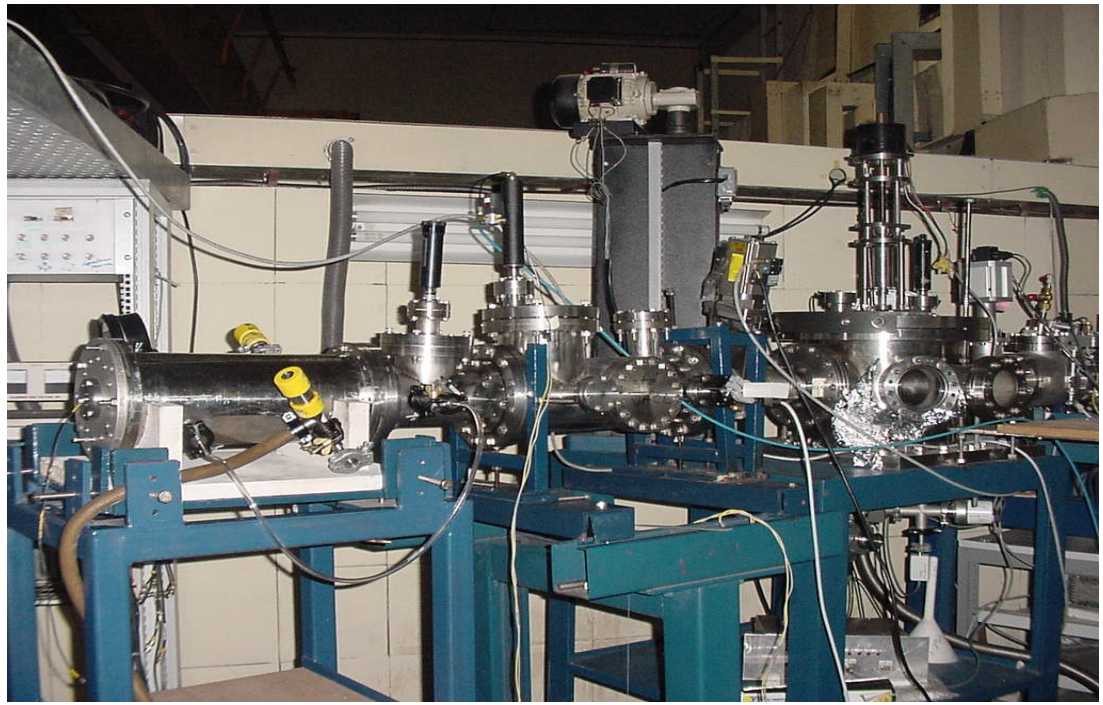
Cryostat modules housing the resonators with liquid He distribution box

Indigenously developed RF Control Stations for LINAC modules

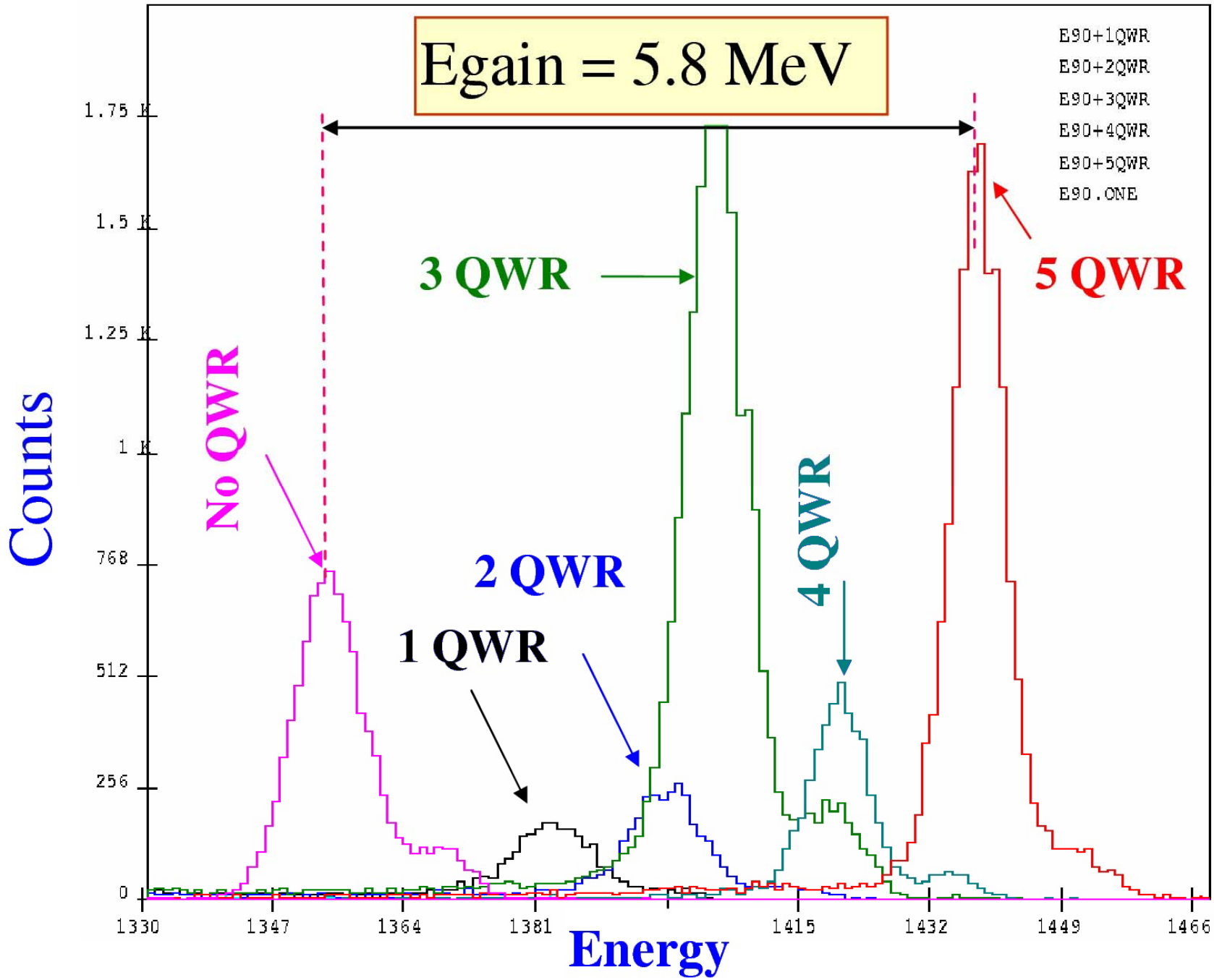


Accelerator Mass Spectrometry

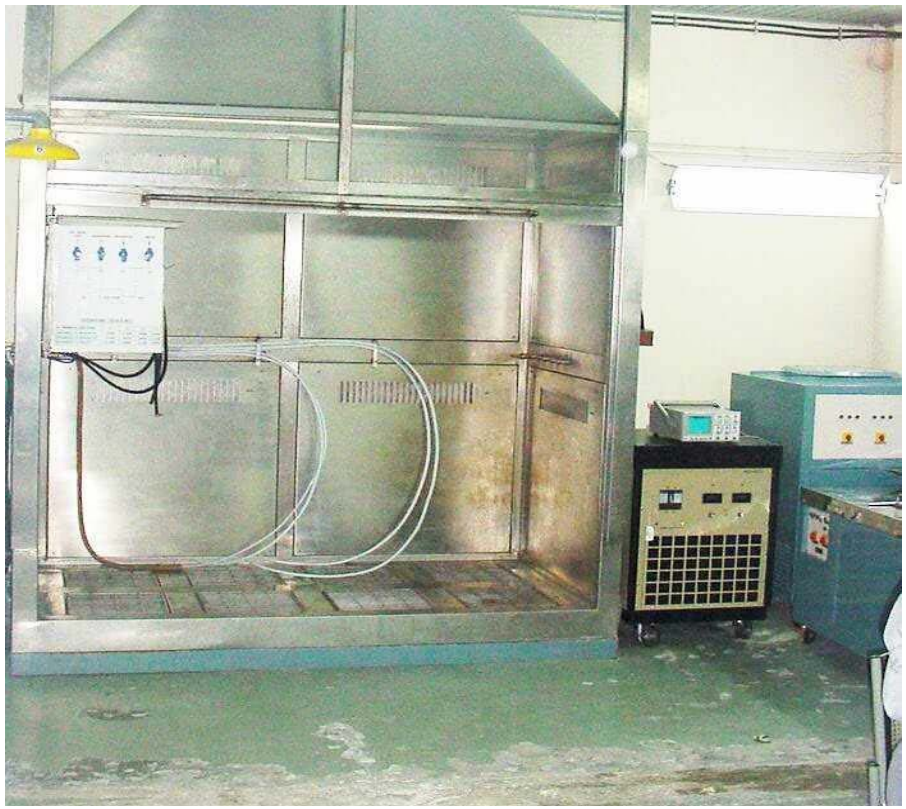
The AMS beam line is now completed. The new AMS chamber has also been put in. For detection of the rare isotope either with a single detector, a solid state telescope or a Multi-Anode Gas Ionization detector.



Cathodes have been prepared from standard ^{10}Be sample, obtained from NIST, USA with collaboration from SINP, Nuclear Chemistry group. A new gas cell has been designed and incorporated in the beam line to absorb ^{10}B and thus to separate ^{10}Be.


Egain = 5.8 MeV
E90+1QWR
E90+2QWR
E90+3QWR
E90+4QWR
E90+5QWR
E90.ONE
No QWR
1 QWR
2 QWR
3 QWR
4 QWR
5 QWR
Counts
Energy
1.75 K
1.5 K
1.25 K
1 K
768
512
256
0
1330
1347
1364
1381
1415
1432
1449
1466

SCRF Facility at NSC

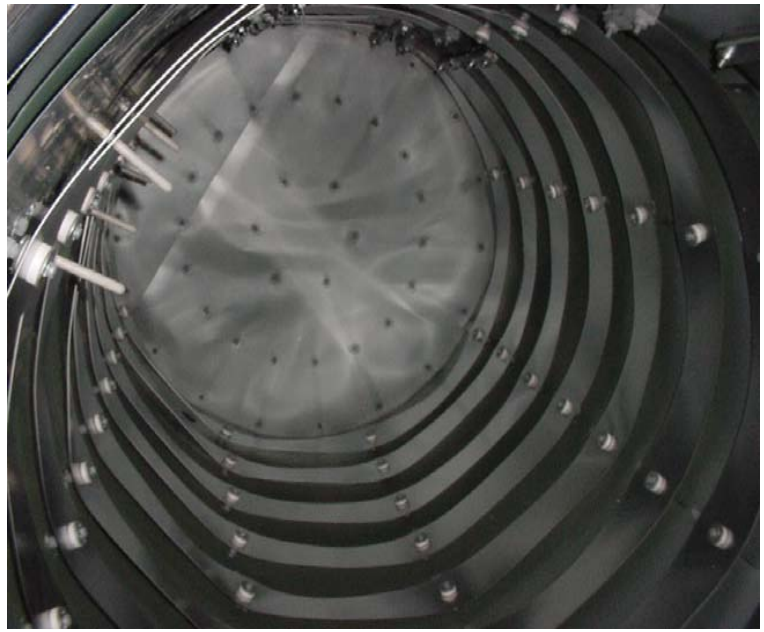


Electro-Polishing

BCP

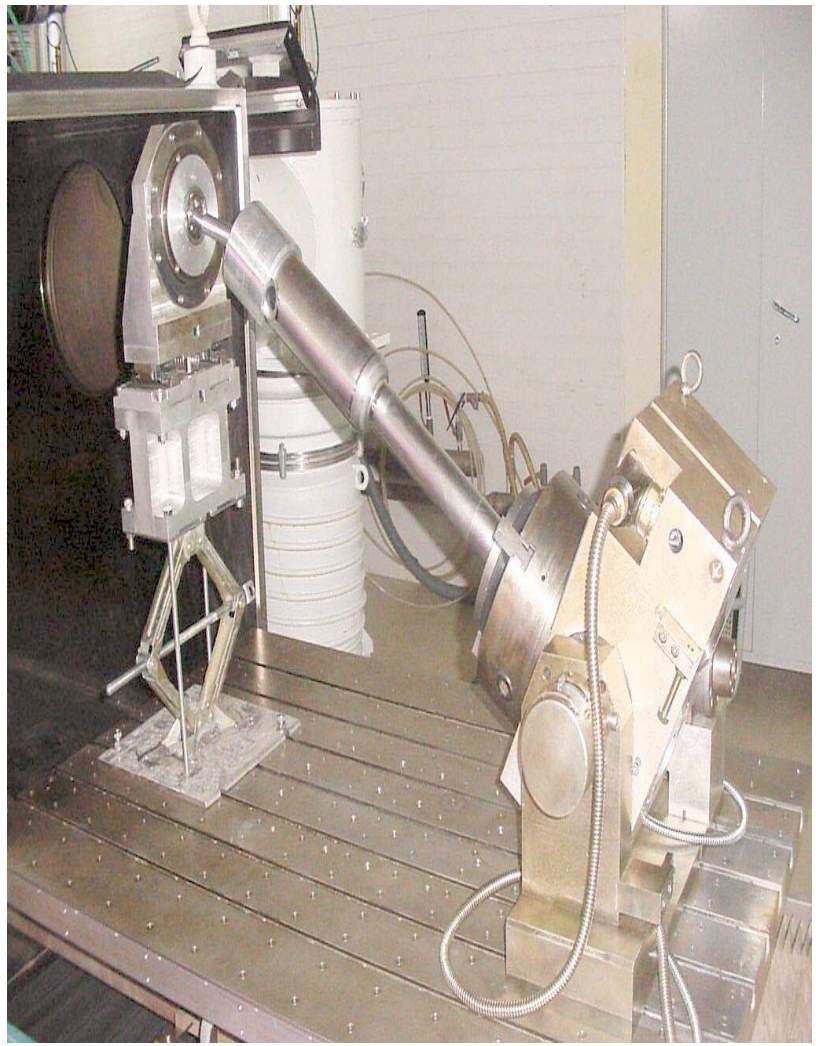
Electron Beam Welding Machine

HIGH VACUUM FURNACE SPECIFICATIONS

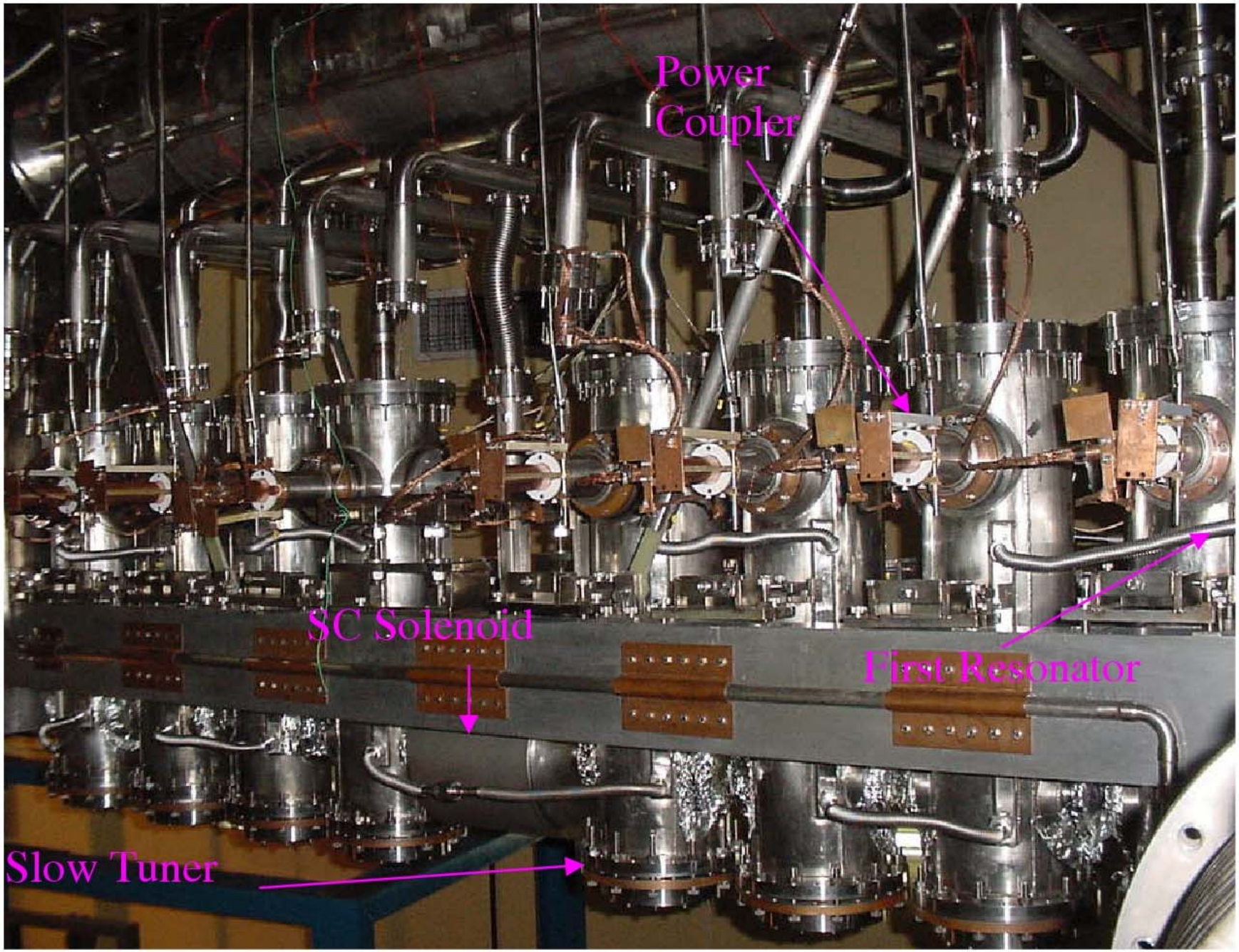


Type	Vertical & Bottom Loading
•Maximum Temperature	1300^{o}C
•Ultimate Base Vacuum	Low 10^{-8} Torr
•Heating Element	Molybdenum
•Operation Mode	Manual/SCADA/AUTO
•Supplier	M/s Hind High Vacuum, Bangalore

SCRF Cavity Build at NSC



One of the two fully indigenously fabricated resonators at NSC along with its slow tuner bellows.


Power
Coupler
SC Solenoid
First Resonator
Slow Tuner

Linac Module with Beam Line and Cryogen distribution lines

World's First High Temperature Superconductor based ECR source installed at NSC.

Proposal: Possible Indian Contributions to Superconducting RF R&D

- R&D to emphasize complete design, construction, testing and industrialization concepts

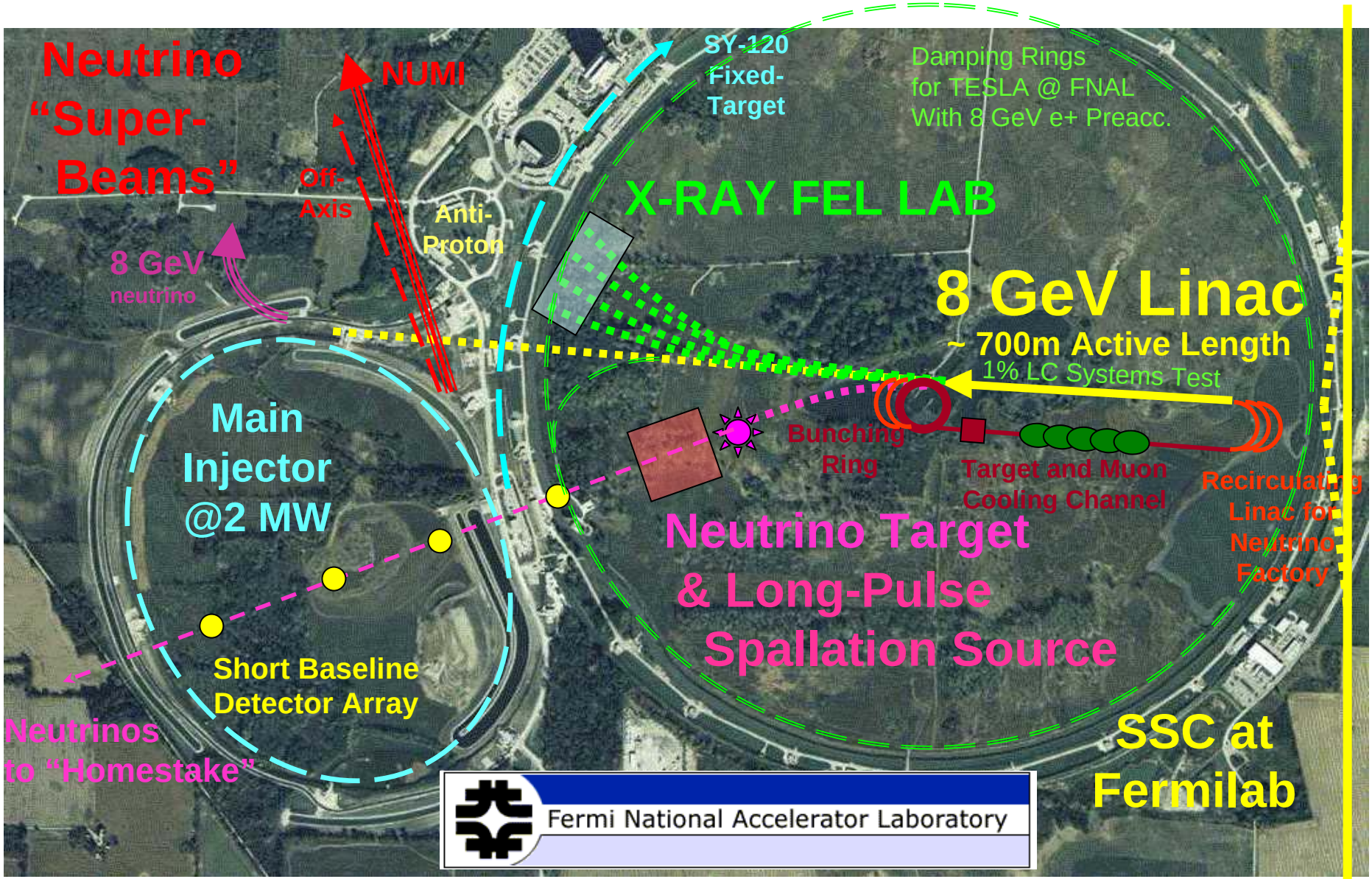
- Possible contributions
  - Beam diagnostics and controls
  - Main Linac RF Power
    - Produce full-scale marx-type induction modulator based on SLAC prototype
    - Build waveguide components such as hybrids, directional couplers (for power distribution or monitoring of power), phase shifters (3-stub tuners), etc.
    - Develop controls for the L-band test stand
    - Industrial production of modulators
  - Main Linac SCRF Structures
    - High gradient RF cavity development
    - SC cryomodule fabrication and industrialization

Proposal: Collaboration on High Intensity Proton Beam

- Both Fermilab and BNL are developing a High Intensity Proton beam proposals to support neutrino physics program.
- Fermilab proton driver is designed such that it can also accelerate electrons and be used as light source.
- All these accelerators uses superconducting RF technology in Linac.
- These accelerators are at R&D stage and it provides a great opportunity for collaboration.
- India has also expressed interest in such an accelerator.
- A new initiative for R&D “SMTF” has started at Fermilab.
- CAT has expressed interest in collaborating on this R&D.

8 GeV Superconducting Linac

With X-Ray FEL, 8 GeV Neutrino & Spallation Sources, LC and Neutrino Factory

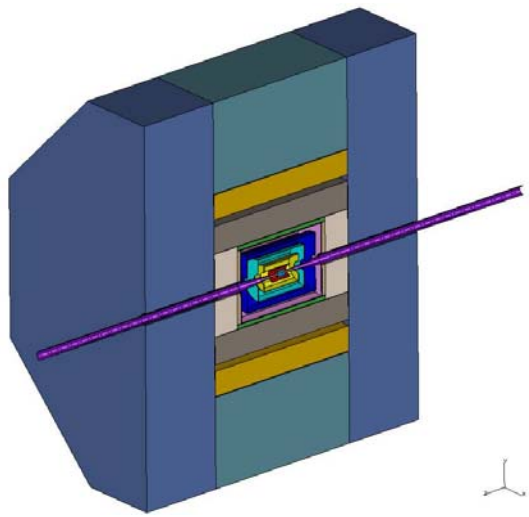


Collaboration: Detector R&D

- At Fermilab India has been collaborating on D0 detector. At CERN India is collaborating on CMS.
- India has helped build Muon, Silicon detectors.
- For ILC a new detector collaboration “SiD” has formed jointly lead by Fermilab and SLAC.

• India has experienced and talented resources that it can contribute to this collaboration in both design and R&D.

• We are developing a proposal to submit on this collaboration



Proposal: Funding Request for Scientific Collaboration between India & US

- Request seed funding to start collaboration
  - Initial request is for three years of funding
  - Money only for people exchange
  - Money for R&D support is being requested separately

- Money to be used to
  - Fund long term (~ 1 year) visit by Indian scientists to US laboratories to work on specific accelerator related R&D
  - Fund accelerator schools in India where US and India can interact
  - Fund short term visit by US and Indian scientists to teach short courses, attend meetings etc.

- Funding Request
  - Long term visits – 5 people @ $40K/year/per person
  - Accelerator schools - $100K/year
  - Short term visits – 20 visits/year @ $5K each

- Total request - $400K/year ; ~$1.2M over three years

Possible Indian Contribution to ILC R&D

- International Linear Collider
  - Open collaboration from the beginning
  - $5-10 billion project - $10 billion cost problematic
  - six years of R&D
  - 5 years of construction
- ILC R&D is estimated to be ~15% of project cost – i.e. ~ $1 billion
- A sizable contribution to ILC R&D from India could be similar to Indian contribution to LHC
- R&D effort will bring technology such as SCRF to India
- India's contribution (both intellectual and industrial) to building ILC is essential to help contain ILC construction costs and make the project feasible

Summary

- In last three years we have come a long way in Indo-US collaboration of Accelerator R&D.
- We think India has the capability to contribute.
- Funding agencies in both countries are positive on these scientific International collaboration.
- US has suggested several areas where India can collaborate.
- International Linear Collider, Proton Driver and Neutrino Physics is of Fermilab interest.
- We need to continue these discussion to soon have a meeting between DOE/NSF and DAE/DST.


Thank
You